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INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	jĭ'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	kĭl'o
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn'ti
10^{-3}	milli	m	mĭl'i
10^{-6}	micro	μ	mi'kro
10^{-9}	nano	n	năn'o
10^{-12}	pico	p	pē'co
10^{-15}	femto	f	fĕm'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.205 lb.
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/mi^2
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 10, Number 9, September 1969

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the Bureau of Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the Bureau of Radiological Health by Federal agencies, State health departments, universities, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators.

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
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Technical Notes

Disposal of Radioactive Wastes from U.S. Naval Nuclear-Powered Ships and Their Support Facilities, 1968

M. E. Miles and *J. J. Mangeno*[1]

This report summarizes data on disposal of radioactive wastes from U.S. Naval nuclear-powered ships and their support facilities and summarizes results of environmental monitoring performed to confirm the adequacy of waste disposal limits and procedures. The waste disposal data show that the total long-lived radioactivity in liquid waste discharges associated with operation and maintenance of Naval nuclear-powered ships totaled 0.10 curie in 1968 for all harbors. This is comparable to 0.39 curie in 1966 and 0.11 curie in 1967 for all harbors, and is less than the average of 4 curies reported discharged per year during 1961 through 1965. Results of environmental surveys of harbor water and bottom sediment for gross radioactivity and for cobalt-60 have shown that, (1) no increase in radioactivity above normal background levels has been detected in harbor water, (2) discharges of liquid wastes from U.S. Naval nuclear-powered ships have not caused a measurable increase over the general background radioactivity of the environment, and (3) low-level cobalt-60 radioactivity is detectable in localized areas of harbor bottom sediment around a few piers at operating bases and shipyards where maintenance and overhaul of Naval nuclear-powered ships have been conducted over a period of several years.

This report confirms that procedures used by the Navy to control discharges of radioactivity from U.S. Naval nuclear-powered ships and their support facilities are effective in protecting the health and safety of the general public.

[1] Nuclear Power Directorate, Naval Ship Systems Command, Department of the Navy.

A detailed description of the means of disposing of radioactive wastes and the sources of these wastes has been presented earlier (*1*). Table 1, which updates information in previous reports (*1–3*), lists the total amount of long-lived radioactivity discharged as liquid wastes into various harbors during the past 5 years. Solid radioactive materials from ships are transferred to a shipyard or other shore facility for packaging and disposal. For ultimate disposal, solid radioactive wastes are shipped to Atomic Energy Commission or State-approved burial sites since shipyards and shore facilities are not permitted to dispose of radioactive solid wastes by burial on their own sites. The total radioactivity and volumes of solid radioactive wastes disposed of from 1964 through 1968 are shown in table 2.

Environmental monitoring survey procedures have been described in a previous report (*1*). A summary of the 1968 surveys for cobalt-60 in bottom sediment of U.S. harbors where U.S. Naval nuclear-powered ships have been regularly based, overhauled, or built is present in table 3.

Once each quarter, a total of at least five water samples is taken at various locations in each harbor in areas where nuclear-powered ships berth and from upstream and downstream locations. These samples are analyzed for gross radioactivity and for cobalt-60. No harbor water sample has shown detectable cobalt-60 radioactivity. No increases in gross radioactivity of harbor water have been detected.

Monitoring for cobalt-60 in harbor bottom sediment is conducted each quarter year by collecting 20 to 100 samples with a 6-inch square sampler. Samples are taken of the top one-half to

Table 1. Radioactive liquid waste discharges to harbors from U.S. Naval nuclear-powered ships and their support facilities for 1964 through 1968[a]

Location[b]	1964		1965		1966		1967		1968	
	Thousand gallons	Curies	Thousand gallons	Curies	Thousand gallons	Curies	Thousand gallons	Curies	Thousand gallons	Curies
Portsmouth, N.H; Naval Shipyard	407	0.13	204	0.24	155	0.01	265	0.01	171	0.01
Quincy, Mass; Quincy Division		[c] ND		ND		ND		ND		ND
Groton-New London, Conn; Electric Boat Div., State Pier and Submarine base	201	1.93	828	1.29	1,274	.03	606	.01	469	.01
Newport News, Va; Newport News Shipbuilding	965	.24	3,360	1.70	1,581	.06	1,533	.04	1,146	.03
Norfolk, Va; Naval Shipyard and base	337	.61	1,146	.44	1,051	.03	1,784	.03		ND
Charleston, S.C; Naval Shipyard and base	294	.36	717	.67	369	.04	320	.01		ND
Pascagoula, Miss; Ingalls Shipbuilding Division		ND		ND		ND		ND		ND
San Diego, Calif; Navy Pier at Ballast Point	35	.40	40	.33		ND		ND		ND
Long Beach, Calif; Naval Shipyard and base		ND		ND		ND		ND		ND
Vallejo, Calif; San Francisco Bay Naval Shipyard	63	.62	128	.21	270	.19		ND	391	.03
Bremerton, Wash; Puget Sound Naval Shipyard		ND	196	.01		ND		ND		ND
Pearl Harbor, Hawaii; Naval Shipyard and base	405	.98	548	.48	654	.03	683	.01	886	.01
Apra Harbor, Guam		ND	69	.01		ND		ND		ND
Total	2,707	5.27	7,236	5.38	5,354	0.39	5,191	0.11	3,063	[d] 0.10

[a] Radioactivity data are reported as if the entire radioactivity consisted of cobalt-60. Volumes are reported prior to dilution.
[b] All other harbors in the U.S. and the rest of the world received a total discharge of 0.013 curies in 1966, 0.001 curies in 1967 and less than 0.001 curies in 1968.
[c] Where discharges in a harbor for a year totaled less than 0.005 curies, ND is reported.
[d] Total of 0.10 curies for 1968 includes discharges reported as ND in this column.

one inch of sediment in the immediate vicinity of and away from berthing areas used by the Naval nuclear-powered ships. These surveys show that the total amount of cobalt-60 observed in bottom sediment near a few piers is small compared to natural radioactivity present in harbors.

Samples from each of these harbors are also checked at least annually by a U.S. Atomic Energy Commission (AEC) laboratory to ensure that analytical procedures are correct and standardized. In addition, the U.S. Navy cooperates with the U.S. Public Health Service (PHS), surveys in some U.S. harbors. Results reported in table 3 are consistent with these AEC and PHS checks.

Twice per year shoreline areas uncovered at low tide are surveyed for radiation levels with sensitive radiation detectors to determine if any

Table 2. Radioactive solid waste disposed of by facilities supporting U.S. Naval nuclear-powered ships for 1964 through 1968[a]

Location	1964		1965		1966		1967		1968	
	Hundred cubic feet	Curies	Hundred cubic feet	Curies	Hundred cubic feet	Curies	Hundred cubic feet	Curies	Hundred cubic feet	Curies
Portsmouth, N.H; Naval Shipyard	80	2.6	150	2.6	194	9.5	300	198.1	314	150.7
Quincy Mass; Electric Boat Division		[b] ND		ND		ND		ND		ND
Groton-New London, Conn.; Electric Boat Div., Tender at State Pier and Submarine base	99	2.3	155	353.0	148	1,092.8	46	17.0	44	20.7
Newport News, Va; Newport News Shipbuilding	22	1.8	198	28.0	70	8.9	167	701.9	144	10.2
Norfolk, Va; Naval Shipyard and tender	5	.5	33	1.6	43	2.5	108	85.6	23	11.2
Charleston, S.C.; Naval Shipyard and tenders	47	1.0	78	111.5	77	5.6	151	52.0	136	109.9
Pascagoula, Miss; Ingalls Shipbuilding Division		ND		ND		ND		ND		ND
San Diego, Calif; Tenders at Ballast Point	7	7.5	3	ND	6	.1	7	.2	14	7.6
Long Beach, Calif; Naval Shipyard and base		ND		ND		ND		ND		ND
Vallejo, Calif. San Francisco Bay Naval Shipyard	9	.3	47	9.4	90	367.0	92	22.8	76	6.6
Bremerton, Wash; Puget Sound Naval Shipyard		ND	4	.1	14	.5	141	192.8	139	48.2
Pearl Harbor, Hawaii; Naval Shipyard and base	13	.7	8	1.4	7	.3	11	1.0	32	5.5
Total	282	16.7	676	507.6	649	1,487.2	1,023	1,271.4	922	370.6

[a] This table includes waste from tenders and nuclear-powered ships since such waste is transferred to support facilities for disposal.
[b] Where total radioactivity is less than 0.05 curies, ND is reported in this table.

Table 3. Summary of 1968 surveys for cobalt-60 in bottom sediment of U.S. harbors where U.S. Naval nuclear-powered ships have been regularly based, overhauled, or built

Location	Number of samples with cobalt-60 concentration of: [a]			Total bottom area with cobalt-60 over 10 pCi/cm² (km²)	Estimated total cobalt-60 in top layer of sediment [b] (Ci)
	<10 pCi/cm²	10–100 pCi/cm²	> 100 pCi/cm²		
Portsmouth, N.H. Naval Shipyard	180	0	0	0	ND
Quincy, Mass. Quincy Division	48	0	0	0	ND
Groton-New London, Conn., Electric Boat Div., State Pier, and Submarine base	189	198	23	0.3	0.1
Newport News, Va. Newport News Shipbuilding	150	1	0	.001	ND
Norfolk, Va., Naval Shipyard and base	336	0	0	0	ND
Charleston, S.C., Naval Shipyard and base	384	0	0	0	ND
Pascagoula, Miss., Ingalls Shipbuilding Division	84	0	0	0	ND
San Diego, Calif., Navy Pier at Ballast Point	168	0	0	0	ND
Long Beach, Calif., Naval Shipyard and base	160	0	0	0	ND
Vallejo, Calif., San Francisco Bay Naval Shipyard	443	0	0	0	ND
Bremerton, Wash., Puget Sound Naval Shipyard	140	0	0	0	ND
Pearl Harbor, Hawaii, Naval Shipyard and base	244	43	1	.3	.02
Apra Harbor, Guam	107	0	0	0	ND

[a] Minimum detectable radioactivity is approximately 2 pCi/cm². Results in units of pCi/g are approximately half the value in pCi/cm².

[b] Total is from areas with cobalt-60 over 10 pCi/cm², which were in the immediate vicinity of piers used for berthing nuclear-powered ships. Where total cobalt-60 is less than 0.01 curie, ND is reported. Core samples more than 1-foot deep from several harbors show that total cobalt-60 present may be two to five times that meeasured in the surface layer.

radioactivity from bottom sediment washed ashore. All results were in the range of 0.01 to 0.04 millirem per hour, the same as background radiation levels in similar areas. Thus, there is no evidence in these ports that radioactivity from sediment is washing ashore.

Throughout the year film badges are posted at locations outside the boundaries of areas where radioactive work is performed. These films showed that radiation exposure to the general public outside these facilities was not above that received from natural background radiation levels.

In addition to the locations listed in table 3, environmental monitoring has been accomplished by the U.S. Navy submarine tenders which serve as operating bases for U.S. Naval nuclear-powered submarines in Rota, Spain, and Holy Loch, Scotland. Results of the surveys in the harbor at Rota, Spain, have not shown detectable cobalt-60 in harbor bottom sediment samples. In 1965, in Holy Loch, more cobalt-60 radioactivity than expected was detected in harbor bottom sediment and on shoreline mud flat areas uncovered at low tide. However, there had been no increase of harbor water radioactivity in Holy Loch above normal background levels. Joint U.S. and British assessments of survey results confirmed that radiation levels in the vicinity of the Holy Loch anchorage were far below those which were at all likely to cause an individual to receive a radiation exposure approaching the limits for members of the general public. Environmental monitoring during 1968 showed that radioactivity levels in Holy Loch are steadily declining.

REFERENCES

(1) VAUGHAN, J. W. and M. E. MILES. Disposal of radioactive wastes from U.S. Naval nuclear-powered ships and their support facilities, 1965. Radiol Health Data Rep 7:257–262 (May 1966).

(2) MILES, M. E. and J. J. MANGENO. Disposal of radioactive wastes from U.S. Naval nuclear-powered ships and their support facilities, 1966. Radiol Health Data Rep 8:699–701 (December 1967).

(3) MILES, M. E. and J. J. MANGENO. Disposal of radioactive wastes from U.S. Naval nuclear-powered ships and their support facilities, 1967. Radiol Health Data Rep 10:135–138 (April 1969).

Summary of Diagnostic X-Ray Statistics Relating Facilities, Equipment, and Personnel by Healing Arts Professions[1]

Lawrence R. Fess[2]

The potential hazard of x-ray emissions from electronic products has been subjected to increasing scrutiny by health agencies and the general public. The need exists for information concerning all sources of exposure to such radiation, including medical and dental x radiation. One area of the problem pursued by the Bureau of Radiological Health is the compilation of information relating to diagnostic x-ray equipment and the operators of such equipment.

Data have been derived, based primarily on the collection of Radiation Protection Survey Reports from States, which provide estimates of the numbers of x-ray machines and of machine operators and practitioners who are involved with the use of x rays in various types of practice.

Table 1 has been constructed to summarize the available statistics on personnel, facilities, and equipment in the field of diagnostic x ray. These provide estimates of the number of practitioners, machines, facilities, operators, and personnel who may be occupationally exposed. As is evident from the footnotes, few of the figures have a simple or direct source, such as a complete count.

To summarize the table briefly, there are an estimated 387,000 non-federal practitioners in the healing arts professions who are directly or indirectly associated with the operation of approximately 207,000 diagnostic x-ray machines. One hundred and twelve thousand of these machines, classified as medical units, are located in approximately 78,000 x-ray facilities that employ 161,000 x-ray machine operators and an additional 34,000 persons who are classified as occupationally exposed personnel. In these medical facilities, an estimated 67,000 persons or about one-third of the occupationally exposed are equipped with personnel monitoring devices. Ninety-four thousand machines located in 86,000 facilities are classified as dental diagnostic type machines. These facilities have approximately 150,000 x-ray machine operators and an additional 21,000 individuals who may be considered as being occupationally exposed. In the dental facilities, an estimated 8,600 persons or 5 percent of the occupationally exposed are equipped with personnel radiation monitoring devices.

[1] Extracted from Radiation Control for Health and Safety Act of 1967, Hearings before the Committee on Commerce, United States Senate, 90th Congress, 2nd session on S2067, S3211, H.R. 10790, Part 2 (May 6, 8, 9, 13, 15, 1968) p. 1051.

[2] Dr. Fess is with the X-ray Section, Division of Medical Radiation Exposure, Bureau of Radiological Health, Rockville, Md. 20852.

Table 1. Estimated numbers of healing arts practitioners and related statistics on diagnostic x-ray facilities, equipment, and personnel by healing arts profession as of June 1965

Healing arts profession	Number of practitioners	Diagnostic x-ray machines			Estimated number of x-ray facilities	Diagnostic X-ray machine personnel					
						Operators		Occupationally exposed		Monitored	
		Average per practitioner[a]	Total per profession[b]	Average per x-ray facility		Average per x-ray facility	Total per profession	Average per x-ray facility	Total per profession	Average per x-ray facility	Total per profession
Physicians total	[c,d]240,212	0.36	86,476	[b]1.64	[e]52,604	[b]2.42	[f]127,334	[b]2.92	[g]153,686	[b]1.20	[h]63,189
Private practice	[c,d](179,641)	(.29)	(52,096)	[b](1.16)	[i](45,015)	[i](2.14)	[i](96,219)	[k](2.57)	[i](115,665)	[l](.74)	[i](33,516)
Hospitals[m]	(60,571)	[b](.57)	(34,380)	[n](4.53)	(7,589)	[o](4.10)	(31,115)	[o](5.01)	(38,021)	[o](3.91)	(29,673)
Osteopaths	[p]11,074	.44	4,872	[o]1.01	4,824	[o]1.49	7,188	[o]1.65	7,900	[o].10	482
Chiropractors and Naturopathe	[q]24,000	.50	12,000	1.00	12,000	[o]1.12	13,440	[o]1.18	14,160	[o].14	1,680
Veterinarians	[r]18,219	.30	5,466	[o]1.05	5,206	[o]1.75	9,110	[o]2.23	11,609	[o].16	833
Podiatrists	[s]7,600	.47	3,572	[t]1.00	3,572	[t]1.00	3,572	[t]2.00	7,144	[t].10	357
Dentists	[u]86,317	[b]1.09	[v]94,174	[t]1.10	85,613	[t]1.75	149,823	[t]2.00	171,226	[t].10	8,561
Total	387,422	—	206,560	—	163,819	—	310,823	—	365,785	—	75,102

[a] From adjustments to best information available primarily in the annual review of Radiological Health Programs, fiscal year 1966, and non-federal practitioners in the healing arts (a composite sheet). Sources: For physicians, AMA Directory Report Service, Volume 16, Supplement 76 (July 1964); for others, National Center for Health Statistics, Health Manpower Statistics Section, PHS, DHEW; and Pocket Data Book, The United States Bureau of the Census, U.S.A. (1967).

[b] Figures were calculated from associated figures presented within the table.

[c] HEALTH RESOURCES STATISTICS. Health Manpower, PHS Publication No. 1509. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (1965).

[d] AMA Directory 17, Supplement 34 (October 4, 1965). This document provides a ratio of the number of physicians both in private practice (code 01, 02) and in hospitals (codes 03, 04, 05, 06) to the total number of physicians, i.e., 241,752 to 267,550. This ratio, when applied to the total number of physicians obtained from the source cited in footnote [c] (266,045), provides the figure 240,212 (physicians in private practice and in hospitals). Note that all of these figures exclude physicians in "government service" and "other" categories as defined by the AMA.

[e] Sum of 7,589 hospital facilities, 5,500 radiologists' offices and 39,515 private offices of other physicians with diagnostic x-ray equipment.

[f] Sum of 31,115 x-ray machine operators in hospital facilities, 20,350 operators in radiologists' offices, and 75,869 operators in private offices of other physicians with diagnostic x-ray equipment.

[g] Sum of 38,021 personnel occupationally exposed in hospital facilities, 23,595 personnel in radiologists offices and 92,070 personnel in private offices of other physicians with diagnostic x-ray equipment.

[h] Sum of 29,673 personnel monitored in hospital facilities; 17,710 personnel in radiologists' offices and 15,806 personnel in private offices of other physicians with diagnostic x-ray equipment.

[i] Footnote [d] reports 5,500 radiologists in private practice. The assumption is made that this number approximates closely the number of radiologists facilities. Data for radiologists' facilities obtained from medical x-ray protection surveys from the States indicates that there are 2.05 diagnostic x-ray machines per such facility: 5,500 × 2.05 = 11,275 x-ray machines in radiologists' offices. This leaves 40,821 diagnostic x-ray machines under the supervision of all other physicians. Data obtained from medical x-ray protection surveys as collected from the States indicates that on the average there are 1.03 diagnostic x-ray machines per facility with such equipment. Hence, 40,821 divided by 1.03 = 39,515 facilities. Therefore, personnel estimates for the group 'physicians in private practice" are composites of best estimates for radiologists' facilities and for facilities of other physicians in private practice.

[j] A composite figure (as explained in footnote [i]). Average number of x-ray machine operators per radiologist's office = 3.70; per other M.D.'s private office = 1.92.

[k] A composite figure (as explained in footnote [i]). Average number of personnel occupationally exposed per radiologist's office = 4.29; per other private practice physicians = 2.33.

[l] A composite figure (as explained in footnote [i]). Average number of personnel monitored per radiologist's office = 3.22; per other physicians private offices = 0.40.

[m] Figures for hospitals were obtained by subtraction of private practice figures from figures presented for physician's total.

[n] This factor was derived by applying the average number of diagnostic x-ray machines in hospitals (as determined from an unpublished document, 'Pilot Study of Characteristics of Practicing X-ray Technicians,") to the number of hospitals obtained from table 6 in "Hospital Statistics" J Amer Hospital Ass 15:474 (August 1, 1967).

[o] Derived from Medical X-ray Protection Surveys sent by the States to the X-ray Section, Medical and Occupational Radiation Program, Bureau of Radiological Health.

[p] HEALTH RESOURCES STATISTICS. Health Manpower, Number of physicians (doctors of osteopathy) for 1965, less federally employed and retired, table 74, p. 74 (1965) PHS Publication No. 1509. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

[q] Ibid., p. 35. Chiropractors, 2nd paragraph, 1st sentence; Naturopaths and allied practitioners, 2nd paragraph, 1st sentence.

[r] Ibid., p. 157, table 121. Total number of veterinarians less retired category and those engaged exclusively in poultry practice.

[s] Ibid., p. 135. Podiatry, 2nd paragraph, 1st sentence.

[t] Estimated.

[u] HEALTH RESOURCES STATISTICS. Health Manpower, Total active non-federal dentists for the United States, table 26, p. 47 (1965) PHS Publication No. 1509. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

[v] NATIONAL CENTER FOR RADIOLOGICAL HEALTH, STATE ASSISTANCE BRANCH. Dental X-ray Program Activities by State, Total Estimated Number of Units, SAB DOC 460-3-66 (June 1966) table 15, p. 27.

SECTION I. MILK AND FOOD

Milk Surveillance, May 1969

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation and/or corrective public health action.

The Pasteurized Milk Network (PMN), sponsored by the Bureau of Radiological Health and the Bureau of Compliance, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations; 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Public Health Service)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that occur in or are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents

Figure 1. Milk sampling networks in the Western Hemisphere

of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variation, expressed in terms of 2-standard deviations, for these concentrations are 1.16 ± 0.08 g/liter and 1.51 ± 0.21 g/liter for calcium and potassium, respectively. These figures are averages of data from the PMN for the period, May 1963–March 1966 (*3*) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Bureau of Radiological Health conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested public health radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted in the spring of 1967, with 40 laboratories participating in an experiment on milk samples containing known concentrations of strontium-90, iodine-131, and cesium-137. Of the 19 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 18 participated in the experiment.

In the majority of cases, the results for the laboratories fell within the 3-standard deviation limits considered appropriate for the various analyses. Several results were outside the 3-standard deviation limits and the most deviant of these represented biases of 20 to 30 percent from the expected values (*5*). Keeping these possible differences in mind, integration of the data from the various networks can be undertaken without introducing a serious error due to disagreement among the independently obtained data.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methodologies, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports*.

A recent article (*6*) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and earlier data articles for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. The frequency of collection and analysis varies not only among the networks, but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium–137 are relatively constant over short-time periods and sampling frequency is not critical. For the case of the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical, and is generally increased at the first measurement or recognition of a new influx of the radionuclide.

The data presentation also reflects whether raw or pasteurized milk was collected. A recent analysis (*7*) of raw and pasteurized milk samples collected during the period, January 1964 to June 1966, indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are

not statistically significant. Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard deviation counting errors or 2-standard deviation total analytical errors from replicate analyses experiments (*3*). The practical reporting level reflects additional analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical errors of precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter
Iodine-131, Cesium-137, Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥100 pCi/liter

For iodine-131, cesium-137, and barium-140 there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions is presented below. The function of the Council is to provide guidance to Federal agencies in the formulation of radiation standards.

Radiation Protection Guides (*8*, *9*)

The Radiation Protection Guide (RPG) has been defined by the Federal Radiation Council (FRC) as the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable. The RPG provides radiation protection guidance for the control and regulation of normal peacetime uses of nuclear technology in which control is exercised primarily at the source through the design and use of nuclear material. It represents a balance between the possible risk to the general public that might result from exposures from routine uses of ionizing radiation and the benefits from the activities causing the exposure.

Table 1 presents a summary of guidelines and related information on environmental radiation levels as set forth by the FRC for the conditions under which RPG's are applicable. A more detailed discussion of these values was presented earlier (*3*).

In the absence of specific dietary data one can use milk as the indicator food item for routine surveillance. Assuming a 1 liter per day intake of milk, one can utilize the graded approach of daily intake on the basis of radionuclide content in milk samples collected to represent general population consumption. Under these assumptions, the radionuclide concentrations in pCi/liter of milk can replace the daily radionuclide intake in pCi/day in the three graded ranges.

Table 1. Radiation Protection Guides—FRC recommendations and related information pertaining to environmental levels during normal peacetime operation

Radionuclide	Critical organ	RPG for individual in the general population (rad/yr)	RPG (rad/yr)	Guidance for suitable samples of exposed population group[a]			
				Corresponding continuous daily intake (pCi/day)	Range I[b] (pCi/day)	Range II[b] (pCi/day)	Range III[b] (pCi/day)
Strontium-89	Bone	[c] 1.5	0.5	[d] 2,000	0–200	200–2,000	2,000–20,000
	Bone marrow	[c] .5	.17				
Strontium-90	Bone	[c] 1.5	.5	[d] 200	0–20	20–200	200–2,000
	Bone marrow	[c] .5	.17				
Iodine-131	Thyroid	1.5	.5	100	0–10	10–100	100–1,000
Cesium-137[e]	Whole body	.5	.17	3,600	0–360	360–3,600	3,600–36,000

[a] Suitable samples which represent the limiting conditions for this guidance are: strontium–89, strontium–90—general population; iodine–131—children 1 year of age: cesium–137—infants.
[b] Based on an average intake of 1 liter of milk per day.
[c] A dose of 1.5 rad/yr to the bone is estimated to result in a dose of 0.5 rad/yr to the bone marrow.
[d] For strontium–89 and strontium–90, the Council's study indicate l that there is currently no operational requirement for an intake value as high as one corresponding to the RPG. Therefore, these intake values correspond to doses to the critical organ not greater than one-third the respective RPG.
[e] The guides expressed here were not given in the FRC reports, but were calculated using appropriate FRC recommendations.

Protective Action Guides (*10, 11*)

The Protective Action Guide (PAG) has been defined by the Council as the projected absorbed dose to individuals in the general population that warrants protective action following a contaminating event. A PAG provides general guidance for the protection of the population against exposure by ingestion of contaminated foods resulting from the accidental release or the unforeseen dispersal of radioactive materials in the environment. A PAG is also based on the assumption that such an occurrence is an unlikely event, and circumstances that might involve the probability of repetitive occurrences during a 1- or 2- year period in a particular area would require special consideration. Protective actions are appropriate when the health benefits associated with the reduction in exposure to be achieved are sufficient to offset the undesirable features of the protective actions.

Table 2 presents a summary of guidelines as set forth by the FRC for the conditions under which PAG's are applicable. A more detailed discussion of these values was presented earlier (*3*). Also given in table 2 are milk concentrations for each of the radionuclides considered, in the absence of others, which, if attained after an acute incident, would result in doses equivalent to the appropriate PAG. These concentrations are based on a projection of the maximum concentration from an idealized model for any acute deposi-

Table 2. Protective Action Guides—FRC recommendations and related information pertaining to environmental levels following an acute contaminating event

Radionuclide	Critical organ	PAG for individuals in general population (rads)	Category (pasture-cow-milk)	
			Guidance for suitable sample, children 1 year of age	
			PAG (rads)	Maximum concentration in milk for single nuclide that would result in PAG (pCi/liter)
Strontium-89	Bone marrow	10 in first yr; total dose not to exceed 15[a,b]	3 in first yr; total dose not to exceed 5[a,b]	[c] 1,110,000
Strontium-90	Bone marrow			[c] 51,000
Cesium-137	Whole body			[c] 720,000
Iodine-131	Thyroid	30	10	[d] 70,000

[a] The sum of the projected doses of these three radionuclides to the bone marrow should be compared to the numerical value of the respective guide.
[b] Total dose from strontium–89 and cesium–137 is the same as dose in first year; total dose from strontium–90 is 5 times strontium–90 dose in first year for children approximately 1 year of age.
[c] These values represent concentrations that would result in doses to the bone marrow or whole body equal to the PAG, if only the single radionuclide were present.
[d] This concentration would result in the PAG dose based on intake before and after the date of maximum concentration observed in milk from an acute contaminating event. A maximum of 84,000 pCi/liter would result in a PAG dose if that portion of intake prior to the maximum concentration in milk is not considered. Children, 1 year of age, are assumed to be the critical segment of the population.

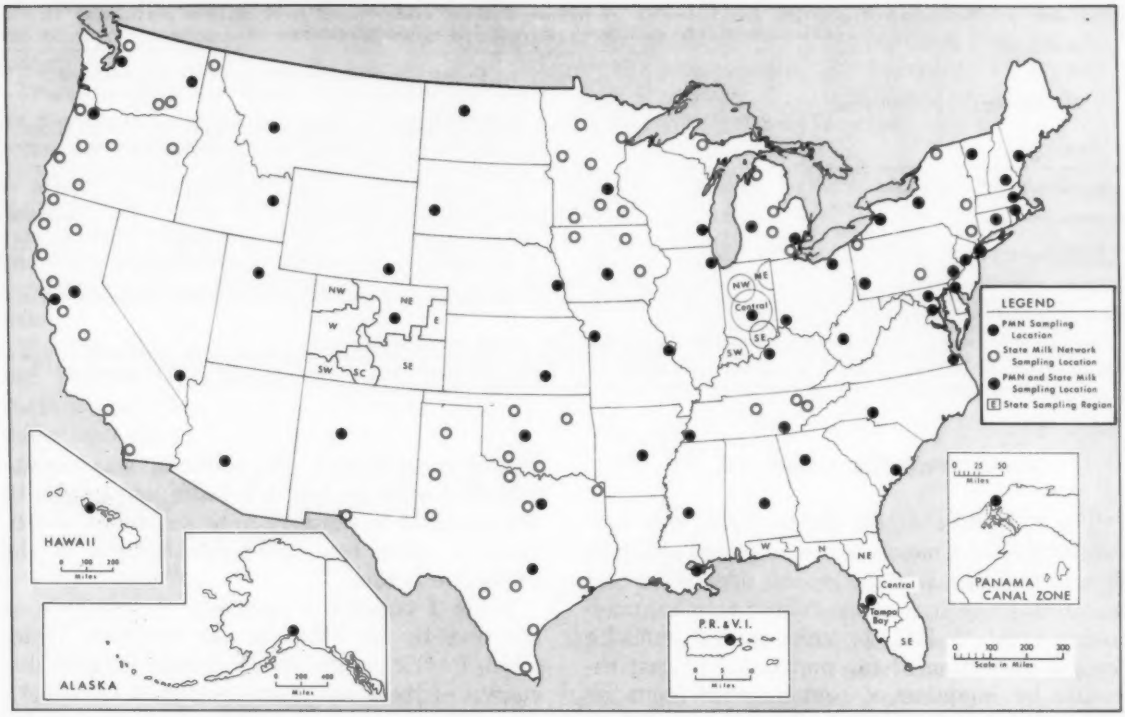

Figure 2. State and PMN milk sampling locations in the United States

tion and the pasture-cow-milk-man pathway, as well as an estimate of the intake prior to reaching the maximum concentration. Therefore, these maximum concentrations are intended for use in estimating future intake on the basis of a few early samples rather than in a retrospective manner.

Data reporting format

Table 3 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports*. (The relationship between the PMN stations and State stations is shown in figure 2.) The first column under each of the radionuclides reported gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12-monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12–month average serves as a basis for comparison.

Discussion of current data

In table 3 surveillance results are given for strontium-90, iodine-131, and cesium-137 for May 1969 and the 12-month period, June 1968 to May 1969. Except where noted the monthly average represents a single sample for the sampling

Table 3. Concentration of radionuclides in milk for May 1969 and 12-month period, June 1968 through May 1969

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average	Monthly average [b]	12-month average
UNITED STATES								
Ala:	Montgomery[c]	P	7	5	0 (5)	0	9 (5)	12
Alaska:	Palmer[c]	P	8	6	0 (3)	0	13 (3)	13
Ariz:	Phoenix[c]	P	0	0	0	0	0 (5)	1
Ark:	Little Rock[c]	P	22	21	0 (4)	0	20 (4)	19
Calif:	Sacramento[c]	P	4	1	0 (4)	0	0 (4)	2
	San Francisco[c]	P	4	2	0 (5)	0	0 (5)	2
	Del Norte	P	22	19	0	0	17	21
	Fresno	P	0	0	0	0	0	3
	Humboldt	P	8	4	0	0	0	11
	Los Angeles	P	0	1	0	0	0	4
	Mendocino	P	5	3	0	0	0	3
	Sacramento	P	4	2	0	0	0	4
	San Diego	P	0	0	0	0	0	3
	Santa Clara	P	0	0	0	0	12	5
	Shasta	P	4	3	0	0	0	6
	Sonoma	P	5	2	0	0	0	3
Colo:	Denver[c]	P	4	5	0 (4)	0	0 (4)	3
	West	R	[d]		[e] (3)	[e]	[e]	[e]
	Northeast	R	[d]		[e] (3)	[e]	[e]	[e]
	East	R	[d]		[e]	[e]	[e]	[e]
	Southeast	R	[d]		NS	[e]	NS	[e]
	South central	R	[d]		NS	[e]	NS	[e]
	Southwest	R	[d]		[e]	[e]	[e]	[e]
	Northwest	R	[d]		[e]	[e]	[e]	[e]
Conn:	Hartford[c]	P	8	9	0 (5)	0	11 (5)	12
	Central	P	6	7	0 (5)	0	7 (5)	10
Del:	Wilmington[c]	P	8	9	0 (4)	0	5 (4)	8
D.C:	Washington[c]	P	9	9	0 (5)	0	2 (5)	5
Fla:	Tampa[c]	P	7	8	0 (4)	0	59 (4)	62
	West	R	12	12	0	3	19	24
	North	R	7	14	0	0	27	33
	Northeast	R	10	9	0	0	79	73
	Central	R	8	9	0	1	29	76
	Tampa Bay area	R	8	8	0	0	63	68
	Southeast	R	8	9	0	0	71	99
Ga:	Atlanta[c]	P	10	12	0 (4)	0	18	19
Hawaii:	Honolulu[c]	P	3	4	0 (4)	0	0 (4)	1
Idaho:	Idaho Falls[c]	P	5	6	0 (4)	0	0 (4)	8
Ill:	Chicago[c]	P	7	8	0 (3)	0	12 (3)	10
Ind:	Indianapolis[c]	P	8	8	0 (4)	0	3 (4)	6
	Northeast	P	9	11	0	0	5	10
	Southeast	P	7	9	0	0	10	9
	Central	P	8	8	0	0	15	11
	Southwest	P	8	8	0	0	15	12
	Northwest	P	10	10	0	0	10	12
Iowa:	Des Moines[c]	P	6	6	0 (4)	0	0 (4)	4
	Iowa City	P	NS					
	Des Moines	P	NS					
	Spencer	P	NS					
	Fredericksburg	P	NS					
Kans:	Wichita[c]	P	9	7	0 (4)	0	0 (4)	3
Ky:	Louisville[c]	P	5	11	0 (5)	0	3 (5)	7
La:	New Orleans[c]	P	19	18	0 (4)	0	22 (4)	21
Maine:	Portland[c]	P	14	12	0 (4)	1	24 (4)	26
Md:	Baltimore[c]	P	11	10	0 (4)	0	6 (4)	8
Mass:	Boston[c]	P	11	12	0 (4)	0	21 (4)	24
Mich:	Detroit[c]	P	8	9	0 (4)	0	10 (4)	11
	Grand Rapids[c]	P	10	11	0 (4)	0	15 (4)	15
	Bay City	P	NA	5	NA	[e]	NA	5
	Charlevoix	P	12	9	[e] (4)	[e]	16 (4)	13
	Detroit	P	4		[e] (4)	[e]	3 (4)	10
	Grand Rapids	P	8	6	[e] (4)	[e]	7 (4)	10
	Lansing	P	5	5	[e] (2)	[e]	7 (2)	4
	Marquette	P	NA	9	[e] (2)	[e]	31 (2)	29
	Monroe	P	NA	3	[e] (2)	[e]	0 (2)	1
	South Haven	P	NA	7	[e] (5)	[e]	11	8
Minn:	Minneapolis[c]	P	10	11	0 (4)	0	2 (4)	14
	Bemidji	P	17	16	0	0	17	22
	Mankato	P	8	7	0	0	14	0
	Rochester	P	9	9	0	0	0	0
	Duluth	P	20	20	0	0	0	28
	Worthington	P	10	7	0	0	0	0
	Minneapolis	P	12	13	0	0	15	14
	Fergus Falls	P	8	9	0	0	12	11
	Little Falls	P	9	10	0	0	13	16
Miss:	Jackson[c]	P	16	15	0 (4)	0	13 (4)	16
Mo.:	Kansas City[c]	P	7	7	0 (5)	0	0 (5)	2
	St. Louis[c]	P	10	9	0 (5)	0	6 (5)	5
Mont:	Helena[c]	P	4	5	0 (3)	0	3 (3)	8
Nebr:	Omaha[c]	P	7	6	0 (5)	0	2 (5)	3
Nev:	Las Vegas[c]	P	0	1	0 (4)	0	0 (4)	1
N.H:	Manchester[c]	P	10	12	0 (4)	0	23 (4)	32

See footnotes at end of table.

Table 3. Concentrations of radionuclides in milk for May 1969 and 12-month period, June 1968 through May 1969—Continued

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average	Monthly average [b]	12-month average
UNITED STATES—Continued								
N.J:	Trenton[c]	P	9	9	0 (4)	0	9 (4)	10
N. Mex:	Albuquerque[c]	P	3	2	0 (4)	0	0 (4)	2
N.Y:	Buffalo[c]	P	7	8	0 (5)	0	7 (5)	10
	New York City[c]	P	10	11	0 (4)	0	5 (4)	14
	Syracuse[c]	P	7	8	0 (4)	0	12 (4)	9
	Albany	P	10	8	0 (4)	0	0 (4)	0
	Buffalo	P	7	0	0	0	0	0
	Massena	P	9	9	0 (2)	0	0 (2)	0
	Newburg	P	5	11	0 (2)	0	0 (2)	0
	New York City	P	12	12	0 (4)	0	0 (4)	0
	Syracuse	P	7	9	0 (2)	0	0 (2)	0
N.C:	Charlotte[c]	P	12	15	0 (4)	0	16 (4)	12
N. Dak:	Minot[c]	P	11	11	0 (2)	0	13 (2)	13
Ohio:	Cincinnati[c]	P	8	9	0 (4)	0	2 (4)	5
	Cleveland[c]	P	8	9	0 (5)	0	9 (5)	8
Okla:	Oklahoma City[c]	P	11	9	0 (3)	0	5 (3)	7
	Oklahoma City	P	NS		NS		NS	
	Enid	P	NS		NS		NS	
	Tulsa	P	NS		NS		NS	
	Lawton	P	NS		NS		NS	
	Ardmore	P	NS		NS		NS	
Ore:	Portland[c]	P	11	8	0 (5)	0	10 (5)	11
	Baker	P	6	3	(e)	(e)	(e)	8
	Coos Bay	P	14	8	(e)	(e)	(e)	15
	Eugene	P	4	4	(e)	(e)	17	13
	Medford	P	4	2	(e)	(e)	(e)	14
	Portland composite	P	8	5	(e)	(e)	(e) (5)	6
	Portland local	P	9	5	(e)	(e)	16 (5)	6
	Redmond	R	4	2	(e)	(e)	(e)	6
	Tillamook	P	14	8	(e)	(e)	30	25
Pa:	Philadelphia[c]	P	9	10	0 (4)	0	1 (4)	8
	Pittsburgh[c]	P	10	12	0 (4)	0	2 (4)	10
	Dauphin	P	8	8	0	0	17	19
	Erie	P	11	11	0	0	15	23
	Philadelphia	P	NS	10	NS	0	NS	18
	Pittsburgh	P	11	11	0	0	15	16
R.I:	Providence[c]	P	8	10	0 (4)	0	12 (4)	19
S.C:	Charleston[c]	P	13	13	0 (4)	0	24 (4)	24
S. Dak:	Rapid City[c]	P	0	8	0 (4)	0	4 (4)	9
Tenn:	Chattanooga[c]	P	11	13	0 (4)	0	6 (4)	13
	Memphis[c]	P	12	10	0 (5)	0	2 (5)	5
	Chattanooga	P	16	11	4	0	13 (4)	16
	Clinton	P	14	13	0 (2)	0	14 (2)	18
	Knoxville	P	11	9	0 (2)	1	14 (2)	10
	Nashville	P	12	9	0 (2)	0	6 (2)	7
Tex:	Austin[c]	P	3	3	0 (4)	0	7 (4)	2
	Dallas[c]	P	10	8	0 (4)	0	4 (4)	7
	Amarillo	R	NS	4	NS	0	NS	2
	Corpus Christi	R	7	4	0	0	0	0
	El Paso	R	3	2	0	0	0	0
	Fort Worth	R	NS	6	NS	0	NS	0
	Harlingen	R	NS	4	NS	0	NS	0
	Houston	R	NS	9	NS	0	NS	0
	Lubbock	R	3	4	0	0	0	2
	Midland	R	NS	3	NS	0	NS	0
	San Antonio	R	NS	2	NS	0	NS	0
	Texarkana	R	5	9	0	0	10	15
	Uvalde	R	NS	2	NS	0	NS	0
	Wichita Falls	R	NS	9	NS	0	NS	0
Utah:	Salt Lake City[c]	P	6	5	0 (4)	0	0 (4)	9
Vt:	Burlington[c]	P	8	9	0 (4)	0	11 (4)	11
Va:	Norfolk[c]	P	11	11	0 (5)	0	7 (5)	9
Wash:	Seattle[c]	P	13	9	0 (5)	0	13 (5)	18
	Spokane[c]	P	8	7	0 (4)	0	1 (4)	7
	Benton County	R	5	1	0	0	0	6
	Franklin County	R	NS	1	NS	0	NS	0
	Sandpoint, Idaho	R	13	9	0	0	22	25
	Skagit County	R	9	6	0	0	29	12
W.Va:	Charleston[c]	P	11	12	0 (3)	0	10 (3)	9
Wisc:	Milwaukee[c]	P	6	7	0 (4)	0	11 (4)	13
Wyo:	Laramie[c]	P	6	5	0 (4)	0	0 (4)	11
CANADA								
Alberta:	Calgary	P	8	8	(d)		9	17
	Edmonton	P	6	8	(d)		13	18
British Columbia:	Vancouver	P	13	13	(d)		34	44
Manitoba:	Winnipeg	P	9	8	(d)		21	24
New Brunswick:	Fredericton	P	11	14	(d)		16	21
Newfoundland:	St. Johns	P	13	19	(d)		17	39
Nova Scotia:	Halifax	P	13	11	(d)		18	20
Ontario:	Ft. William	P	15	16	(d)		24	33

See footnotes at end of table.

Table 3. Concentration of radionuclides in milk for May 1969 and 12-month period, June 1968 through May 1969—Continued

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average	Monthly average [b]	12-month average
CANADA—Continued								
Ontario:	Ottawa	P	7	8	[d]		10	18
	Sault Ste. Marie	P	16	15	[d]		27	34
	Toronto	P	5	5	[d]		7	14
	Windsor	P	5	6	[d]		8	13
Quebec:	Montreal	P	7	8	[d]		15	19
	Quebec	P	12	12	[d]		29	28
Saskatchewan:	Regina	P	7	7	[d]		10	17
	Saskatoon	P	10	9	[d]		15	17
CENTRAL AND SOUTH AMERICA								
Columbia:	Bogota	P	NS	1	NS	0	NS	0
Chile:	Santiago	P	0	0	0	0	0	0
Ecuador:	Guayaquil	P	0	0	0	0	0	0
Jamaica:	Mandeville	P	3	5	0	0	60	100
Venezuela:	Caracas	P	0	1	0	0	0	0
Canal Zone:	Cristobal[e]	P	0	2	0 (4)	1	6 (4)	14
Puerto Rico:	San Juan[e]	P	4	5	0 (4)	0	9 (4)	8
PMN network averages[f]			8	8	0	0	8	11

[a] P, pasteurized milk; R, raw milk.
[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.
[e] PHS Pasteurized Milk Network station. All other sampling locations are part of the State or national network.
[d] Radionuclide analysis not routinely performed.
[e] The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for these networks were equal to or less than the following practical reporting levels:

Iodine-131: Colorado—25 pCi/liter; Michigan—14 pCi/liter; Oregon—15 pCi liter
Cesium-137: Colorado—25 pCi/liter; New York—20 pCi/liter; Oregon—15 pCi/liter

[f] This entry gives the average radionuclide concentrations for the PHS pasteurized milk network stations denoted by footnote [e].
NA, no analysis.
NS, no sample collected.

station. Strontium-89 and barium-140 data have been omitted from table 3 since levels at the great majority of the stations for May 1969 were below the respective practical reporting levels. Table 4 gives monthly averages for those stations at which and barium-140 was detected.

Table 4. Barium-140 in milk, May 1969

Sampling location	Monthly average (pCi/liter)
	Barium-140
Tenn: Chattanooga (State)	6(4)
Clinton (State)	6(2)
Knoxville (State)	6(2)

Iodine-131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower values reflected by the radiation protection guidance provided by the Federal Radiation Council (see table 1), levels in milk for this radionuclide are of particular public health interest. In general, the practical reporting level for iodine-131 is numerically equal to the upper value of Range I (10 pCi/liter) of the FRC radiation protection guide.

Strontium-90 monthly averages ranged from 0 to 22 pCi/liter in the United States for the month of May 1969 and the highest 12-month average was 21 pCi/liter (Little Rock, Ark.,) representing 10.5 percent of the Federal Radiation Council radiation protection guide (table 1). Cesium-137 monthly averages ranged from 0 to 79 pCi/liter in the United States for the month of May 1969 and the highest 12-month average was 76 pCi/liter (central Florida), representing 2.1 percent of the value presented in this report using the recommendations given in the Federal Radiation Council reports. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (*12*) and Jamaica. Iodine-131 results for individual samples were all below the practical reporting level except Chattanooga, Tenn. (State) 4 pCi/liter.

Acknowledgment

Appreciation is expressed to the personnel of the following health agencies who provide data for their milk surveillance networks:

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Division of Environmental Sanitation
California State Department of Health

Radiological Health Section
Division of Air, Occupational, and Radiation Hygiene
Colorado State Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Division of Radiological Health
Bureau of Preventable Diseases
Florida State Board of Health

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiological Health Service
Division of Occupational Health
Michigan Department of Health

Radiation Protection Division
Canadian Department of National Health and Welfare

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Health
Division of Environmental Health Services
New York State Department of Health

Division of Occupational and Radiological Health
Environmental Health Services
Oklahoma State Department of Health

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Office of Air Quality Control
Division of Technical Services
Washington State Department of Health

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Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows:

Program	Period reported	Issue
California Diet Study	November 1967–September 1968	May 1969
Connecticut Diet Study	January–June 1968	November 1968
Institutional Diet Study, *PHS*	October–December 1968	July 1969
Tri-City Diet, *HASL*	January–June 1968	April 1969

SECTION II. WATER

The Public Health Service, the Federal Water Pollution Control Administration and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	July–December 1967	November 1968
Colorado River Basin	1967	December 1968
Drinking Water Analysis Program	1961–1966	August 1968
Florida	1967	February 1969
Kansas	July–December 1967	November 1968
Minnesota	January–June 1968	February 1969
North Carolina	January–December 1967	May 1969
Radiostrontium in Tap Water, *HASL*	January–June 1968	April 1969
Washington	July 1967–June 1968	June 1969

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Gross Radioactivity in Surface Waters of the United States February 1969

Division of Pollution Surveillance
Federal WaterPollution Control Administration
Department of the Interior

The monitoring of levels of radioactivity in surface waters of the United States was begun in 1957 as part of the Water Pollution Surveillance System currently operated by the Federal Water Pollution Control Administration. Table 1 presents the current preliminary results of the alpha and beta radioanalyses. The radioactivity associated with dissolved solids provides a rough indication of the levels which would occur in treated water, since nearly all suspended matter is removed by treatment processes. Strontium-90 results are reported semiannually. The stations on each river are arranged in the table according to their distance from the headwaters. Figure 1 indicates the average total beta radioactivity in suspended-plus-dissolved solids in raw water collected at each station. A description of the sampling and analytical procedures was published in the November 1968 issue of *Radiological Health Data and Reports*.

Complete data and exact sampling locations for 1958 through 1963 are published in annual compilations (*1–6*). Data for subsequent years are available on request.

Special note is taken when the alpha radioactivity is 15 pCi/liter or greater or when the beta radioactivity is 150 pCi/liter or greater. These arbitrary levels provide a basis for the

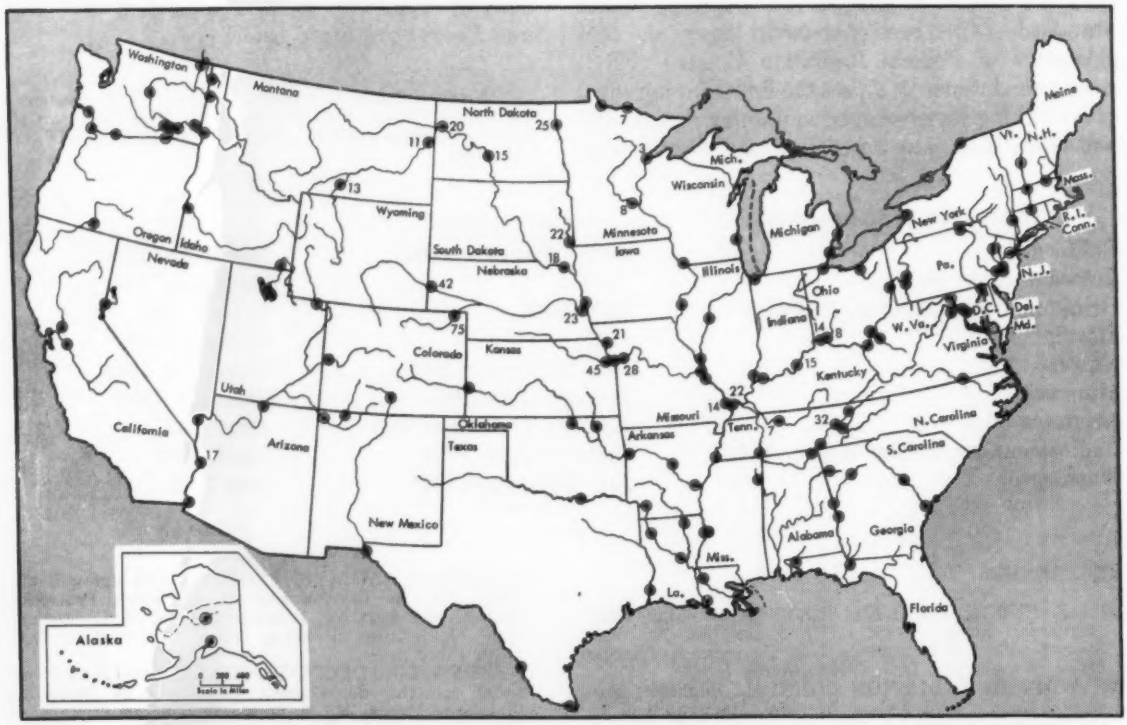

Figure 1. Sampling locaions and associated total beta radioactivity (pCi/liter) in surface waters, February 1969

Table 1. Radioactivity in raw surface waters, February 1969

Station	Average alpha radioactivity (pCi/liter)			Average beta radioactivity (pCi/liter)		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
BIG HORN RIVER:						
Hardin, Mont.	0	4	4	2	11	13
BIG SIOUX RIVER:						
Sioux Falls, S. Dak.	0	5	5	1	21	22
CLINCH RIVER:						
Kingston, Tenn.[a]	0	0	0	1	31	32
COLORADO RIVER:						
Parker Dam, Calif–Ariz.	0	9	9	1	16	17
CUMBERLAND RIVER:						
Cheatham Lock, Tenn.	1	0	1	4	3	7
GREAT LAKES:						
Duluth, Minn.	0	0	0	0	3	3
KANSAS RIVER:						
DeSoto, Kans.	13	2	15	32	13	45
LITTLE MIAMI RIVER:						
Cincinnati, Ohio	1	0	1	5	3	8
MISSISSIPPI RIVER:						
St. Paul, Minn.	0	1	1	0	8	8
Cape Girardeau, Mo.	1	0	1	5	9	14
MISSOURI RIVER:						
Williston, N. Dak.	1	3	4	9	11	20
Bismarck, N. Dak.	0	3	3	2	13	15
Yankton, S. Dak.	0	2	2	0	18	18
St. Joseph, Mo.	1	7	8	2	19	21
Missouri City, Mo.	3	3	6	14	14	28
NORTH PLATTE RIVER:						
Henry, Nebr.	<1	30	30	4	38	42
OHIO RIVER:						
Cincinnati, Ohio	3	0	3	10	4	14
Louisville, Ky.	1	1	2	8	7	15
Cairo, Ill.	6	0	6	16	6	22
PLATTE RIVER:						
Plattsmouth, Nebr.	1	4	5	4	19	23
RAINY RIVER:						
International Falls, Minn.	0	0	0	0	7	7
RED RIVER, NORTH:						
Grand Forks, N. Dak.	0	1	1	3	22	25
SOUTH PLATTE RIVER:						
Julesburg, Colo.	1	38	39	9	66	75
YELLOWSTONE RIVER:						
Sidney, Mont.	0	2	2	0	11	11
Maximum	13	38	39	32	66	75
Minimum	0	0	0	0	3	3

[a] Gross beta radioactivity at this station may not be directly comparable to gross beta radioactivity at other stations because of the possible contribution of radionuclides from an upstream nuclear facility in addition to the contribution from fallout and naturally occurring radionuclides.

selection of certain data for comment. They reflect no public health significance as the Public Health Service drinking water standards have already provided the basis for this assessment. Changes from or toward these arbitrary levels are also noted in terms of changes in radioactivity per unit weight of solids. A discussion of gross radioactivity per gram of solids for all stations for 1961 through 1965 has been presented (*7*). Comments are made only on monthly average values. Occasional high values from single weekly samples may be absorbed into a relatively low average. When these values are significantly high, comment will be made.

During February 1969, the following stations showed alpha radioactivity values in excess of 15 pCi/liter for either suspended or dissolved solids:

North Platte River; Henry, Nebr.
South Platte River; Julesburg, Colo.

None of the stations showed a beta radioactivity value in excess of 150 pCi/liter during February 1969.

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Radioactivity in New York Surface Waters July-December 1968

Division of General Engineering and Radiological Health
State of New York Department of Health

In 1955 the New York State Department of Health began a program to determine the amount of radioactivity in water used for public consumption. Radioactivity in water may arise from any one or a combination of the following sources: the natural mineral content of water (background), atmospheric fallout, or nuclear industry operations.

Analytical procedures

A measured quantity of water, usually 500 ml, is evaporated and the residue is analyzed for its beta component in an end window, gas flow, proportional counter.

Strontium and alkaline earths are precipitated as carbonates from a 500-ml sample. Iron and rare earths are removed by hydroxide scavenging, while barium is precipitated as a chromate. Strontium is finally precipitated as a sulphate from a pH controlled EDTA solution. Calcium and yttrium remain in solution as EDTA complexes (1–2).

Strontium-90 is determined by yttrium-90 ingrowth counting of the final precipitate at less than 6 hours after precipitation and again at greater than 50 hours using a low background (less than 1 cpm) gas-flow, proportional beta-particle counter. Strontium-89 is estimated by

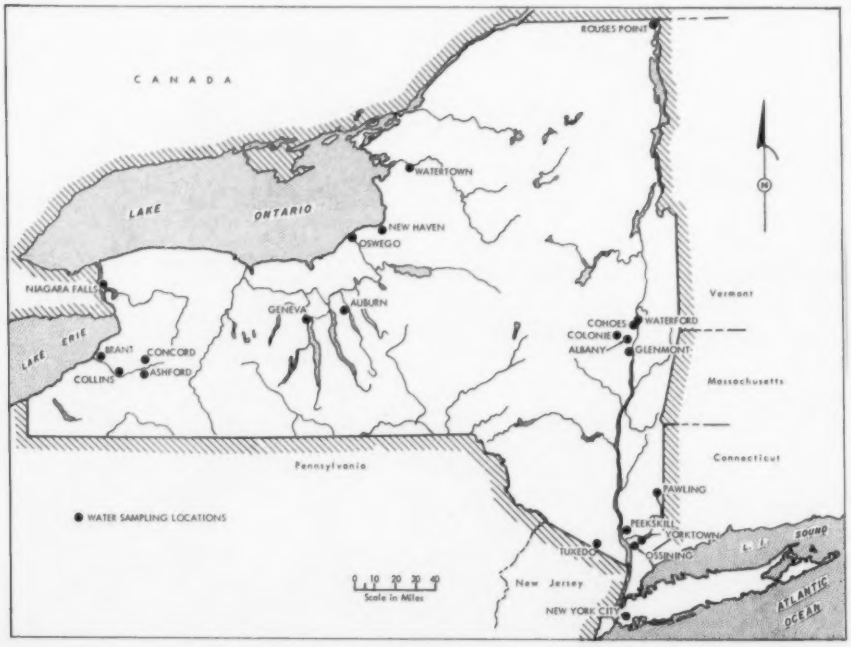

Figure 1. New York water sampling locations

Table 1. Gross beta radioactivity in New York raw surface waters, July–December 1968[a]

Location	Gross beta radioactivity (pCi/liter)							
	July-September 1968				October-December 1968			
	Number of samples	Average	Maximum	Minimum	Number of samples	Average	Maximum	Minimum
Albany	2	3	3	2	3	2	3	2
Ashford (Buttermilk Creek at Fox Valley Road)	3	9	18	4	3	5	6	4
(Buttermilk Creek at Thomas Corners)[b]	16	1,518	2,589	110	12	896	2,141	190
(Cattaraugus Creek at Bigelow Bridge)	3	7	12	3	3	6	10	3
(Cattaraugus Creek at Felton Bridge)	5	282	721	153	—	NA	NA	NA
Brant (Cattaraugus Creek)	13	47	67	29	12	60	123	26
Cohoes (Filtration Plant)	11	3	6	1	11	3	7	2
Collins (Cattaraugus Creek)	13	74	185	29	13	66	103	32
Concord (Cattaraugus Creek)	42	123	275	6	63	148	253	31
Geneva (Seneca Lake)	3	4	5	3	3	3	4	3
Glenmont (Hudson River)	12	4	7	2	11	4	7	2
New Haven (Lake Ontario)	3	4	4	1	2	4	4	4
New York City	6	3	4	1	2	2	3	ND
Niagara Falls (West Branch, Niagara River)	3	4	4	3	2	4	4	4
Ossining (Indian Brook Reservoir)	3	5	5	5	3	5	5	5
(Sing Sing) (Hudson River)	12	31	59	ND	12	33	60	ND
Oswego	1	2	NA	NA	3	4	4	4
Pawling (Pond at United Nuclear)	5	3	4	2	4	3	3	3
Peekskill (Camp Field Water Supply)	3	5	10	ND	3	ND	ND	ND
(Hudson River)	11	21	38	3	11	25	46	ND
Tuxedo (Indian Kill)	4	4	4	1	3	3	4	3
Watertown (Black River)	11	2	4	2	7	4	5	3
Yorktown (Croton Reservoir)	3	4	4	3	3	3	4	3

[a] Excluding tritium.
[b] This station is on the Nuclear Fuels Services reprocessing plant site.
NA, no analysis.
ND, nondetectable.

Table 2. Strontium-90 concentration in New York surface waters, July–December 1968

Location	Strontium-90 (pCi/liter)							
	July–September 1968				October–December 1968			
	Number of samples	Average	Maximum	Minimum	Number of samples	Average	Maximum	Minimum
Ashford (Buttermilk Creek at Thomas Corners)[a]	19	360	1,015	72	10	465	871	187
(Cattaraugus Creek at Felton Bridge)	1	231	NA	NA	—	NA	NA	NA
Concord (Springville Power Dam on Cattaraugus Creek)	3	25	38	15	1	38	NA	NA

[a] This station is on the Nuclear Fuels Services reprocessing plant site.
NA, no analysis.

taking the difference between the total strontium and the strontium-90 radioactivity.

Chemical recovery is between 70 and 75 percent and results in a minimum detectable radioactivity of 3 pCi/liter ±100 percent at the 95 percent confidence level.

Tritium in water is determined by liquid scintillation counting of 3 ml of distilled sample in 17 ml of scintillator solution. The scintillator solution consists of 4 g PPO, 0.25 g dimethyl POPOP and 120 g naphthalene dissolved in 1 liter of dioxane. The sample is counted twice for a total of 100 minutes using either a Packard Tri-Carb model 3315 or a Beckman LS 200B Liquid scintillation spectrometer. Minimum sensitivites at the 95 percent confidence level ±100 percent are 1,000 pCi/liter for the Tri-Carb and 500 pCi/liter for the Beckman.

Discussion and results

With the exception of Buttermilk and Cattaraugus Creeks downstream of Nuclear Fuel Services, the results of water sampling stations in the State remain low. Water samples are obtained from 23 locations for gross beta-particle analysis (figure 1). The type of sample, number of samples, quarterly average, maximum and minimum gross beta-particle concentrations in New York surface water for July-December 1968 are given in table 1.

Table 3. Tritium concentration of New York surface waters, July–December 1968

Location	Concentration (pCi/liter)							
	July–September 1968				October–December 1968			
	Number of samples	Average	Maximum	Minimum	Number of samples	Average	Maximum	Minimum
Albany	3	ND	1,590	ND	3	1,000	1,130	ND
Ashford (Buttermilk Creek at Fox Valley Road)	3	ND	ND	ND	3	ND	1,120	ND
(Buttermilk Creek at Thomas Corners)[a]	14	658,900	1,134,000	149,900	12	71,380	266,500	3,390
(Cattaraugus Creek at Bigelow Bridge)	3	1,700	4,190	ND	3	ND	1,040	ND
(Cattaraugus Creek at Felton Bridge)	5	54,970	95,040	32,680		NA	NA	NA
Brant (Cattaraugus Creek)	11	27,440	50,350	10,480	12	8,980	29,820	2,410
Cohoes (Filtration Plant)	11	ND	2,200	ND	11	ND	1,500	ND
Collins (Cattaraugus Creek)	13	33,960	69,440	6,770	13	10,540	39,770	1,100
Concord (Springville Power Dam on Cattaraugus Creek)	41	51,510	110,400	7,350	62	16,950	71,670	2,700

[a] This station is on the Nuclear Fuels Services reprocessing plant site.
ND, nondetectable.
NA, no analysis.

Larger samples are collected at selected locations for strontium-90 analysis. The number of samples, average, maximum, and minimum concentrations of strontium-90 in New York water for the third and fourth quarters of 1968 are given in table 2 for three stations where strontium-90 was detected.

Tritium concentration values for the third and fourth quarters of 1968 are given in table 3 for nine locations. Tritium, the radioactive isotope of hydrogen, a very low energy beta-particle emitter is released to the water courses during the reprocessing of nuclear fuel. The tritium concentrations in Cattaraugus and Buttermilk Creeks showed the contribution of the Nuclear Fuel reprocessing plant.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
June–December 1967	October 1968
January–June 1968	April 1969

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SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

An intercomparison of the above networks was performed by Lockhart and Patterson in 1962 and is summarized in the January 1964 issue of *Radiological Health Data*. In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports*.

Network	Period	Issue
HASL Fallout Network	July–December 1967	September 1968
HASL 80th Meridian Network	Calendar Year 1966	December 1968
Plutonium in Airborne Particulates	January–March 1968	January 1969

1. Radiation Alert Network May 1969

Bureau of Radiological Health
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 73 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate Bureau of Radiological Health officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Radiological Surveillance Branch, Division of Environmental Radiation, BRH, Rockville, Md. A detailed description of the sampling and analytical procedures was presented in the April 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during May 1969. Time profiles of gross beta radioactivity in air for eight Radiation Alert Network stations are shown in figure 2.

All field estimates reported were within normal limits for the reporting station.

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, May 1969

Station location		Number of samples	Air surveillance, gross beta radioactivity (pCi/m³)			Last profile in RHD&R	Number of samples	Precipitation			
								Total depth (mm)	Field estimation of deposition		
		Air	Maximum	Minimum	Average [a]				Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	21	5	0	2	Feb 69	4	125	4	125	26
Alaska:	Adak	21	2	1	1	Feb 69	[c]				
	Anchorage	10	0	0	0	Oct 68	[c]				
	Attu Island	23	0	0	0	Mar 69	[c]				
	Fairbanks	[b]				Sept 69	[c]				
	Juneau	21	0	0	0	Dec 68	9	140	8	137	0
	Kodiak	[b]				Jan 69	[c]				
	Nome	[b]				May 69	[c]				
	Point Barrow	30	0	0	0	Apr 69	[c]				
	St. Paul Island	10	1	1	1	June 69	[c]				
Ariz:	Phoenix	21	7	1	4	Dec 68	[c]				
Ark:	Little Rock	6	4	0	2	Aug 69	[c]				
Calif:	Berkeley	21	1	0	0	Jan 69	1	20	0	0	[e]
	Los Angeles	21	1	0	0	May 69	[c]				
C.Z:	Ancon	17	0	0	0	Jan 69	[c]				
Colo:	Denver	18	7	1	2	Jan 69	5	182	[d]		
Conn:	Hartford	21	1	0	0	Sept 69	6	59	6	59	0
Del:	Dover	20	1	0	0	July 69	[c]				
D.C:	Washington	16	1	0	0	Apr 69	2	9	2	9	0
Fla:	Jacksonville	19	2	0	1	Aug 69	5	57	5	57	55
	Miami	17	0	0	0	Sept 69	11	229	10	223	0
Ga:	Atlanta	20	2	1	1	June 69	3	229	3	229	238
Guam:	Agana	[b]				July 69	[c]				
Hawaii:	Honolulu	27	6	0	1	Mar 69	[c]				
Idaho:	Boise	18	4	1	2	Mar 69	4	17	4	17	0
Ill:	Springfield	19	5	1	3	Apr 69	[c]				
Ind:	Indianapolis	20	2	0	2	June 69	3	36	3	36	41
Iowa:	Iowa City	18	4	0	1	Jan 69	4	89	4	89	0
Kans:	Topeka	19	3	0	1	Aug 69	3	92	3	92	0
Ky:	Frankfort	3	1	1	1	Apr 69	[c]				
La:	New Orleans	20	1	0	1	Apr 69	8	161			
Maine:	Augusta	21	1	0	0	May 69	8	68	8	68	0
Md:	Baltimore	21	1	0	0	Sept 69	2	20	2	20	12
	Rockville	12	1	0	1	Mar 69	[c]				
Mass:	Lawrence	20	1	0	0	July 69	4	26	4	26	2
	Wincheater	21	2	0	1	Feb 69	4	36	4	36	0
Mich:	Lansing	21	4	0	2	Mar 69	7	102	7	102	152
Minn:	Minneapolis	21	1	0	0	July 69	9	42	9	42	6
Miss:	Jackson	18	2	0	1	May 69	1	25	1	25	0
Mo:	Jefferson City	21	2	0	1	June 69	8	68	8	68	0
Mont:	Helena	20	9	1	4	Feb 69	1	1	1	1	2
Nebr:	Lincoln	16	4	1	3	June 69	4	67	4	67	18
Nev:	Las Vegas	14	2	0	1	Sept 69	[c]				
N.H:	Concord	21	1	0	0	Apr 69	[c]				
N.J:	Trenton	21	3	0	1	May 69	1	15	1	15	0
N. Mex:	Santa Fe	6	2	0	1	Feb 69	4	40	4	40	0
N.Y:	Albany	15	3	0	1	June 69	6	69	6	69	59
	Buffalo	21	2	0	1	Jan 69	[c]				
	New York City	20	1	0	0	Feb 69	[c]				
N.C:	Gastonia	17	12	1	5	Jan 69	2	28	[d]		
N.Dak:	Bismarck	20	3	1	2	Apr 69	5	35	5	35	0
Ohio:	Cincinnati	[b]				July 69	[c]				
	Columbus	16	6	0	1	May 69	5	73	0	0	[e]
	Painesville	19	2	0	1	Sept 69	6	66	6	66	0
Okla:	Oklahoma City	18	1	0	0	Mar 69	3	74	3	74	0
	Ponca City	21	2	0	1	Sept 69	5	63	5	63	27
Ore:	Portland	17	1	0	1	June 69	7	33	7	33	6
Pa:	Harrisburg	2	0	0	0	June 69	[c]				
P.R:	San Juan	[b]				May 69	[c]				
R.I:	Providence	20	1	0	0	Mar 69	4	30	4	30	23
S.C:	Columbia	14	2	0	1	Feb 69	2	71	2	71	9
S. Dak:	Pierre	8	6	2	4	Dec 68	[c]				
Tenn:	Nashville	7	2	0	1	Mar 69	2	23	2	23	0
Tex:	Austin	20	6	1	2	July 69	5	65			
	El Paso	[b]				Apr 69	[c]				
Utah:	Salt Lake City	20	6	1	2	May 69	2	3	2	3	1
Vt:	Barre	20	2	0	1	Aug 69	10	81	10	81	0
Va:	Richmond	21	0	0	0	Aug 69	4	52	4	52	9
Wash:	Seattle	8	1	0	0	Aug 69	7	52	[d]		
	Spokane	21	2	0	1	July 69	[c]				
W. Va:	Charleston	14	3	0	1	Feb 69	6	41	6	41	6
Wisc:	Madison	20	2	0	1	Aug 69	9	67	9	67	51
Wyo:	Cheyenne	21	10	2	4	Sept 69	3	42	3	42	20
Network summary		1,180	12	0	1		5	65	5	62	20

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] No report received. (Air samples received without field estimate data are not considered by the data program.)
[c] No precipitation sample collected.
[d] This station is part of the plutonium in precipitation network. No gross beta measurements are done.
[e] Samples were collected but no field estimates were received.

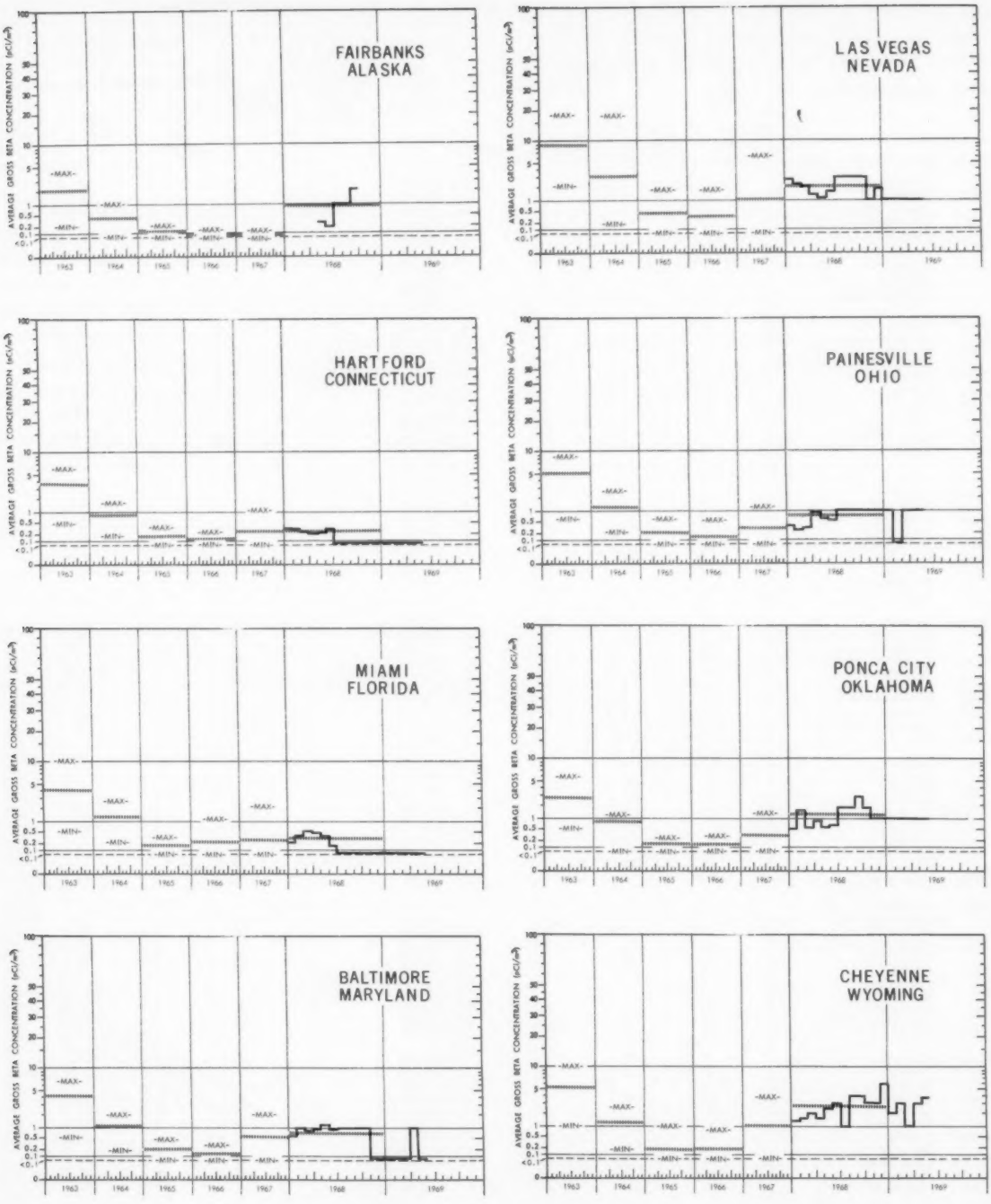

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Alert Network, 1963–May 1969

2. Canadian Air and Precipitation Monitoring Program[1] May 1969

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meterological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the August 1969 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for May 1969 are presented in table 2.

[1] Prepared from information and data in the June 1969 monthly report "Data from Radiation Protection Program," Canadian Department of National Health and Welfare, Ottawa, Canada.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, May 1969

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	26	0.7	0.0	0.3	N8	N8
Coral Harbour	31	.1	.0	.1	31	1.0
Edmonton	31	.5	.0	.2	193	6.4
Ft. Churchill	30	.2	.0	.1	45	1.5
Ft. William	17	.3	.0	.2	138	8.9
Fredericton	29	.3	.0	.1	65	4.5
Goose Bay	31	.2	.0	.1	15	.8
Halifax	30	.4	.0	.1	56	4.6
Inuvik	31	.2	.0	.1	82	1.0
Montreal	31	.4	.0	.2	83	7.9
Moosonee	31	.3	.0	.1	21	8.3
Ottawa	30	.4	.0	.2	88	6.0
Quebec	30	.3	.0	.1	51	8.3
Regina	31	.7	.0	.2	245	6.0
Resolute	28	.2	.0	.1	30	.2
St. John's, Nfld	30	.2	.0	.1	59	7.9
Saskatoon	31	.5	.0	.2	128	5.8
Saulte Ste. Marie	31	.5	.1	.2	144	8.5
Toronto	30	.5	.0	.2	65	4.7
Vancouver	31	.5	.0	.2	179	4.7
Whitehorse	30	.5	.0	.2	207	1.0
Windsor	31	.4	.0	.2	52	6.1
Winnipeg	31	.5	.1	.2	130	9.9
Yellowknife	31	.2	.0	.2	48	1.0
Network summary	703	0.7	0.0	0.2	94	4.7

N8, no sample.

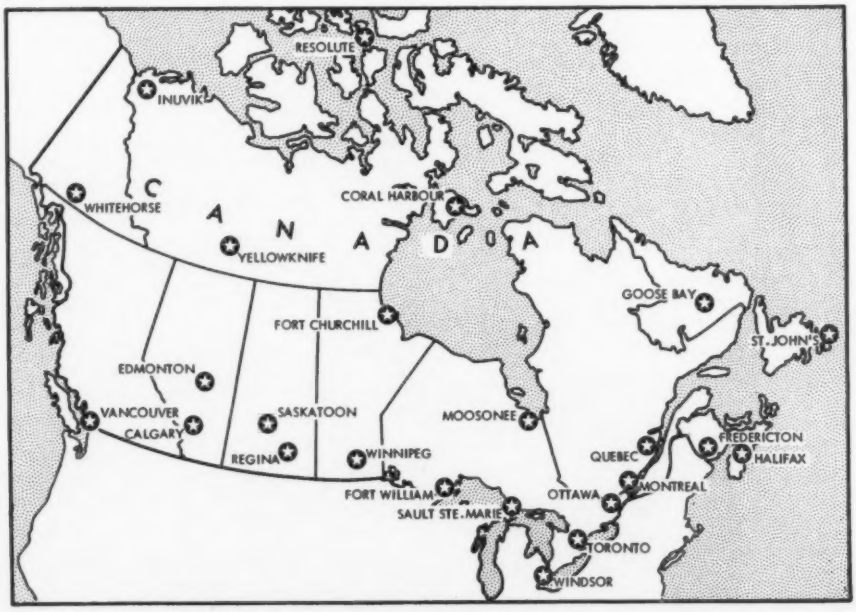

Figure 3. Canadian air and precipitation sampling stations

3. Pan American Air Sampling Program May 1969

Pan American Health Organization and *U.S. Public Health Service*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 4. Analytical techniques were described in the January 1968 issue of *Radiological Health Data and Reports*. The May 1969 air monitoring results from the participating countries are given in table 3.

Figure 4. Pan American Air Sampling Program station

Table 3. Summary of gross beta radioactivity in Pan American surface air, May 1969

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average[a]
Argentina:	Buenos Aires	11	0.10	0.02	0.06
Bolivia:	La Paz	12	.35	.11	.23
Chile:	Santiago	31	.70	.32	.46
Colombia:	Bogota	14	.47	.16	.28
Ecuador:	Cuenco	23	.26	.00	.10
	Guayaquil	20	.32	.11	.23
	Quito	10	.26	.12	.22
Guyana:	Georgetown	15	.93	.66	.78
Jamaica:	Kingston	20	.41	.13	.28
Peru:	Lima	NS			
Venezuela:	Caracas	19	.34	.11	.22
West Indies:	Trinidad	17	.33	.17	.26
Pan American summary		192	0.70	0.00	0.29

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.
NS, no sample.

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SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, bovine thyroid sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Strontium-90 in Human Bone, July-September 1968[1]

Bureau of Radiological Health
Public Health Service

To obtain data on the concentration of strontium-90 in man by age and geographical region, the Public Health Service began collecting human bone specimens in late 1961. Analyses of selected samples of people in older-age groups have shown their bone strontium-90 content to be low and age-independent (*1*). Consequently, the target population includes children and young adults up to 25 years of age.

Although a few samples come from living persons as a result of surgical procedures, the majority are obtained post mortem. In the latter case, the specimens are limited to accident victims or persons who have died of an acute disease process that was not likely to impair bone metabolism. For analytical purposes, a sample of at least 100 grams of wet bone is desired. Generally, this amount is readily available from older children, but it presents some difficulties from the standpoint of infants and children under 5 years of age. Most specimens received to date have been vertebrae and ribs.

[1] Period during which death or surgical procedure occured.

Laboratory procedures

The bones are analyzed at Northeastern Radiological Health Laboratory of the Bureau of Radiological Health, at Winchester, Mass. Sample collection and preparation are explained else-

Figure 1. Geographical regions for human bone sampling

Table 1. Strontium-90 in human bone, July–September 1968

Bone region and State		Bone type[a]	Age[b] (years)	Sex	Strontium-90 concentration[c] (pCi/kg bone)	Calcium concentration (g/kg bone)	^{90}Sr/Ca (pCi/g)
Northeast:	N.J	V, R, S	0	F	087.7± 7.8	20.9	4.19
		V, S	1	F	51.2± 5.2	18.3	2.79
	Mass	V	2	M	11.6±13.0	25.5	0.45
	R.I	V	3	M	82.9±10.0	27.5	3.01
	N.Y	V	3	F	169.0±16.0	53.7	3.14
	Conn	R, T	9	M	297.0±25.0	93.4	3.17
	Vt	V	9	F	92.8± 7.6	31.8	2.91
	Vt	V	9	F	92.8± 7.6	31.8	2.91
	N.Y	V	12	F	104.0± 8.3	37.4	2.78
	Conn	V, R	12	M	61.7± 6.8	28.6	2.15
	Mass	V	13	M	112.0± 8.5	43.1	2.59
		V	14	M	63.3± 6.4	28.6	2.21
	Maine	V	15	M	252.0±13.0	49.5	5.09
	Mass	V	18	M	146.0±11.0	39.1	3.73
	N.Y	V	18	M	162.0±13.0	43.9	3.69
		V	18	M	139.0±10.0	41.6	3.34
	Conn	V	18	M	77.5± 7.1	35.9	2.15
	N.Y	V	19	F	102.0± 9.4	45.1	2.26
	Pa	V	19	M	91.7± 9.4	44.9	2.04
	N.Y	V	19	M	159.0±11.0	48.4	3.28
	Vt	V	20	F	70.6±10.0	51.5	1.37
	N.Y	V	20	M	105.0± 9.3	47.2	2.22
	Maine	V	21	M	178.0±14.0	46.4	3.83
	Conn	V, R	22	M	102.0±12.0	50.1	2.03
	N.Y	V	22	M	110.0±12.0	75.4	1.45
	N.Y	V	25	F	100.0± 8.8	41.6	2.40
Southeast:	S.C	V	2	M	208.0±27.0	60.3	3.44
		V	2	F	164.0±15.0	53.9	3.04
		V	5	M	277.0±18.0	36.7	7.54
	Md	V	9	M	77.8± 9.8	36.5	2.13
	S.C	V	11	F	91.2± 8.9	29.7	3.07
	Md	V	12	M	66.1± 7.0	34.8	1.89
		V	12	F	90.9±10.0	36.7	2.47
		V	13	M	83.9±10.0	38.0	2.20
		V	13	M	82.0±11.0	29.3	2.79
		V	13	M	102.0± 9.4	37.8	2.69
	S.C	V	13	M	62.7± 6.9	30.7	2.04
	Ga	V	14	M	120.0±11.0	44.7	2.68
	Md	V	16	F	194.0±18.0	53.6	3.61
		V	16	M	158.0±12.0	58.9	2.68
		V	17	M	97.8± 9.3	51.7	1.89
		V	17	M	222.0±13.0	45.6	4.86
		V	18	F	103.0±15.0	58.8	1.75
		V	18	M	135.0±12.0	49.1	2.74
		V	18	F	163.0±13.0	50.1	3.25
	S.C	V	18	M	152.0±10.0	52.1	2.91
	Md	V	19	M	105.0±10.0	49.8	2.10
		V	19	M	227.0±18.0	59.7	3.80
		V	19	M	112.0±12.0	51.8	2.16
		V	19	M	122.0±11.0	49.3	2.47
		V	19	F	97.5± 9.2	55.4	1.75
	S.C	V	21	M	130.0± 9.7	46.0	2.82
		V	21	M	104.0±15.0	57.6	1.80
	Md	V	21	M	98.8± 8.3	49.0	2.01
	S.C	V	22	M	163.0±11.0	46.1	3.53
	Md	V	22	M	71.9± 7.3	50.3	1.42
		V	23	M	73.9± 9.7	53.9	1.37
		V	23	M	120.0±10.0	62.0	1.93
		V	24	M	59.3± 6.9	39.4	1.50
		V	24	M	108.0±12.0	61.6	1.75
Central:	Wisc	V	0	F	180.0±22.0	55.0	3.27
		V	0	M	125.0±16.0	55.0	2.27
	Mich	V	3	F	91.6± 8.8	31.9	2.87
	Minn	V	4	F	82.2± 7.4	22.8	3.60
		V	4	F	111.0± 9.2	30.5	3.63
	Wisc	V	5	M	185.0±14.0	44.6	4.14
	Ohio	V	7	M	234.0±16.0	70.0	3.34
		V	9	F	186.0±18.0	93.3	1.99
	Wisc	V	9	M	37.4± 6.3	26.9	1.39
	Ohio	V	9	M	138.0±12.0	55.7	2.47
		V	12	F	124.0±34.0	65.3	1.89
	Mich	V	14	F	89.5± 8.8	37.4	2.39
	Ohio	V	14	M	119.0±11.0	50.5	2.35
		V	14	M	122.0±13.0	56.2	2.17
	Minn	V	16	F	52.6± 6.4	28.2	1.86
	Mich	V	17	M	80.0±12.0	56.8	1.40
	Ohio	V	18	M	164.0±12.0	57.6	2.84
		V	19	F	102.0±12.0	75.6	1.34
	Minn	V	19	M	86.8± 7.5	43.9	1.97
	Ohio	V	20	M	93.8±12.0	61.3	1.53
		V	20	M	210.0±22.0	82.0	2.56
		V	21	M	107.0±13.0	56.9	1.88
		V	24	M	90.0±12.0	75.3	1.19
		V	24	M	117.0±13.0	67.2	1.74
	Miss	V	25	F	125.0±14.0	51.1	2.44

See footnotes at end of table.

Table 1. Strontium-90 in human bone, July–September 1968—Continued

Bone region and State		Bone type[a]	Age[b] (years)	Sex	Strontium-90 concentration[c] (pCi/kg bone)	Calcium concentration (g/kg bone)	$^{90}Sr/Ca$ (pCi/g)
Northwest:	Ore	V	0	M	155.0±14.0	50.8	3.05
		V	1	M	90.7± 9.3	47.3	1.91
		V	4	F	33.2± 5.1	27.5	1.20
		V	6	F	50.1± 6.5	32.8	1.52
		V	8	M	65.7± 8.5	34.3	1.91
		V	8	F	43.3± 6.8	29.5	1.46
		V	9	M	89.0± 8.4	33.0	2.69
		V	12	M	58.9± 6.3	35.8	1.64
		V	12	M	58.9± 6.3	35.8	1.64
		V	13	M	286.0±19.0	104.0	2.75
		V	16	M	124.0±10.0	47.0	2.63
	Wash	V	17	M	146.0±11.0	58.2	2.50
	Ore	V	18	M	122.0±12.0	49.7	2.45
		V	18	F	88.9± 8.2	51.6	1.72
		V	18	F	99.1±12.0	52.6	1.88
		V	21	M	99.9±13.0	59.6	1.67
		V	22	M	78.1± 7.4	48.3	1.61
		V	22	M	110.0±12.0	50.5	2.17
Southwest:	Tex	V	0	M	291.0±19.0	36.1	8.06
	Colo	V	7	M	110.0±16.0	56.7	1.94
	Tex	V	11	F	98.4± 9.7	33.7	2.91
	Colo	V	13	F	77.0±13.0	40.7	1.89
		V	15	M	96.1± 8.7	42.5	2.26
		V	16	M	155.0±13.0	54.8	2.82
		V	17	F	129.0±12.0	61.1	2.11
		V	18	F	96.5±12.0	52.9	1.82
		V	18	M	92.9± 8.2	45.7	2.03
		V	19	M	86.0±11.0	58.8	1.46
		V	20	M	99.1± 8.9	51.9	1.90
	Calif	V	21	M	64.2±10.0	51.8	1.23
	Colo	V	22	F	60.8± 8.8	50.7	1.19
		V	22	M	64.3± 7.9	48.4	1.32
		V	23	F	82.5± 9.4	52.3	1.57
		V	24	F	110.0±13.0	57.0	1.92
		V	24	M	72.8±10.0	50.7	1.43
North:	Alaska	R	20	M	383.0±34.0	152.0	2.51

[a] Type of bone: vertebrae, V; rib, R; sternum, S; tibia, T.
[b] Age given as of last birthday prior to death.
[c] Two-sigma counting error.

where (*2*). Strontium-90 is measured by tributyl phosphate extraction of its yttrium daughter, which is precipitated as an oxalate. The strontium-90 content is than calculated (*3*) from the yttrium-90 activity. For the purpose of maintaining analytical reproducibility, "blind" duplicate analyses are performed on 10 to 20 percent of the samples. To further check and maintain analytical accuracy, synthetic "bone ash" samples (calcium phosphate spiked with strontium-90) are analyzed periodically.

The analytical results for strontium-90 in individual bones from persons dying during the third quarter (July–September) of 1968 are presented in table 1 in order of increasing age within each geographical region. These regions are indicated in figure 1. Reported values are given in picocuries of strontium-90 per kilogram of bone (as a rough indication of dose) and per gram of calcium (for comparison with other data and for purposes of model development). Two-sigma counting errors are reported for the bone concentration.

Following the pattern of earlier reports, subsequent articles will continue to provide interpretation of the data at appropriate stages in the program (*2–5*).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1967	October 1968
October–December 1967	February 1969
January–March 1968	April 1969
April–June 1968	July 1969

REFERENCE

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(*5*) HALLISEY. R. M. and M. A. WALL. Strontium-90 in human bone, 1964–1965. Radiol Health Data Rep 8:415–9 (August 1967).

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major AEC installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the AEC Manual.[1]

Summaries of data from the environmental radioactivity monitoring reports follow for the Hanford Atomic Products Operation and the Los Alamos Scientific Laboratory.

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation," contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Hanford Atomic Products Operation[2] Calendar Year 1967

Battelle Memorial Institute
Richland, Washington

A variety of radioactive wastes are generated by the Hanford production reactors, chemical separations plants, and laboratories. High level wastes are concentrated and retained in storage within the project boundaries. Controlled releases of low-level wastes, for which concentration and storage are not feasible, are made to the ground, to the atmosphere, and to the Columbia River. The Atomic Energy Commission (AEC) regulations governing radioactive waste disposal at Hanford are described in the AEC Manual Chapter RL 0510 (*1*). During 1967, the plant facilities were operated for the AEC by: Atlantic Richfield Hanford Company; Pacific Northwest Laboratory of Battelle Memorial Institute: Douglas United Nuclear, Incorporated; Isochem, Incorporated; and ITT Federal Support Services, Incorporated.

The Hanford plant is located in a semiarid region of southeastern Washington State, where the average annual rainfall is about 16 cm (6 in.). This section of the State has a sparse covering of natural vegetation primarily suited for grazing, although large areas near the project have gradually been put under irrigation during the past few years. The plant site (figure 1) covers an area of about 1,300 km² (500 square miles). The Columbia River flows through the northern edge of the project and forms part of the eastern boundary. Near the plant production sites, the prevailing winds are from the northwest with strong drainage and crosswinds causing distorted flow patterns. The meteorology of the region is typical of desert areas with frequent strong inversions occurring at night and breaking during the day to provide unstable and turbulent conditions.

The populated area of primary interest is the tri-cities area (Richland, Pasco, and Kennewick) situated on the Columbia River directly downstream from the plant (figure 1). Smaller communities in the vicinity are Benton City, West Richland, Mesa, and Othello. The population of the communities near the plant, together with the surrounding agricultural area, is about 90,000.

Sources and levels of environmental radioactivity

Low-level wastes from plant operations, fallout from nuclear weapons testing, naturally-occurring radionuclides, and cosmic rays contribute to radiation levels in the Hanford environs. Hanford operations that could contribute to radioactivity outside the plant boundary are, the disposal of reactor cooling water to the Columbia River, stack releases at the chemical separations areas and laboratory areas, and disposal of radioactive wastes to ground.

The most significant Hanford contribution to off-plant radioactivity and population doses usually originates with reactor cooling water releases to the Columbia River. Although airborne re-

[2] Summarized from Pacific Northwest Laboratory, Evaluation of Radiological Conditions in the Vicinity of Hanford for 1967, BNWL-983 (March 1969).

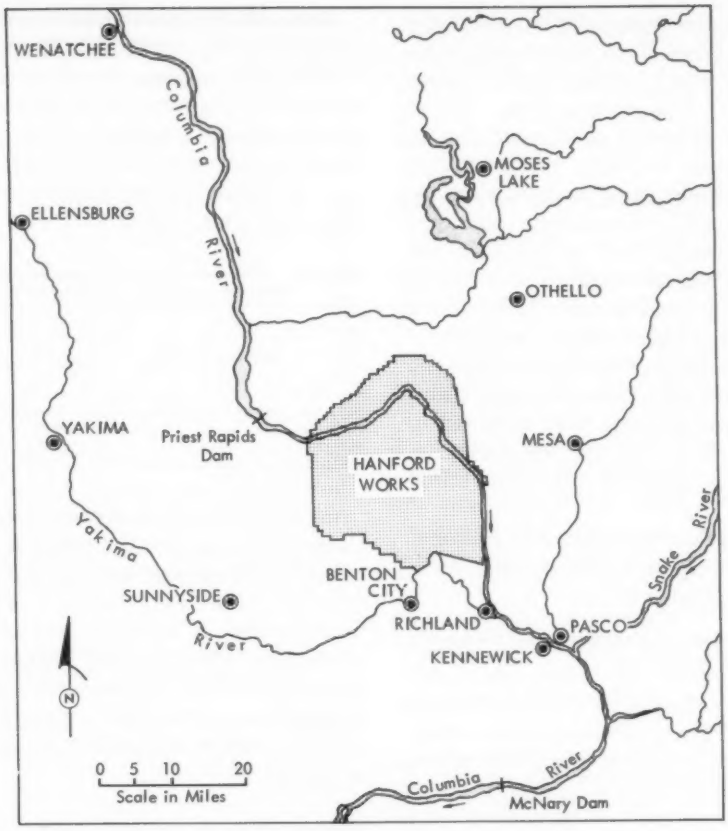

Figure 1. Hanford project environs

leases of iodine-131 contributed to the thyroid doses of the local population, the major portion of the thyroid dose in 1967 resulted from radioiodines in drinking water.

Noteworthy events during 1967 included the June shutdown of D reactor, the fourth Hanford production reactor to be retired since 1964. The Redox separations plant was also retired from routine operation. Abrupt but temporary increases in iodine-131 concentrations in environmental media in January 1967 were attributed to an announced foreign weapons test.

Radioactivity in the Columbia River

All of Hanford's production reactors use Columbia River water for cooling. The N-reactor uses recirculating demineralized water as a primary coolant. All wastewater containing significant amounts of radioactive materials is filtered through the ground before it reaches the river. The amount of radioactive material reaching the river from N-reactor is a negligibly small fraction of that released from the older reactors.

At the older reactors, some elements present in the cooling water are transformed into radionuclides during the single pass through the reactors. In addition, radioactive materials formed on the surfaces of fuel elements and process tubes are eventually carried away by the cooling water to the river.

Many of the radionuclides formed in reactor cooling water are short-lived and decay rapidly after formation. In addition to radioactive decay, some fraction of most radionuclides is removed from the river water by sedimentation and uptake by aquatic organisms. Relatively small amounts of fission products are present in the river because of occasional ruptures of the fuel element jackets and fallout from nuclear weapons testing.

Samples of river water were collected above the production areas at Priest Rapids Dam and below the areas at the Richland water plant intake, McNary Dam and Bonneville Dam. Where possible, cumulative sampling equipment was installed and provided a more representative sample than the periodic grap samples obtained in the past. This cumulative sampling technique, however, makes it impractical to calculate the amounts of very short-lived nuclides; these must still be measured from grab samples. Comparison of 1967 with 1965 concentrations indicates a general reduction for most radionuclides with the exception of phosphorus-32. Lower concentrations of the short-lived radionuclides were expected in 1967 because production reactors remaining in operation are further upstream than the retired reactors.

The annual average concentrations of radionuclides measured routinely at Richland and Bonneville Dam are shown in table 1.

Table 1. Annual average radioactivity in Columbia River water, 1967

Radioactivity	Radioactivity concentration (pCi/liter)	
	Richland	Bonneville Dam
Rare earths + yttrium	390	(a)
Sodium-24	2,600	(a)
Phosphorus-32	190	25
Chromium-51	3,200	1,400
Copper-64	2,000	(a)
Zinc-65	220	62
Arsenic-76	400	(a)
Strontium-90	1	(a)
Antimony-122	150	(a)
Iodine-131	8	3
Neptunium-239	1,100	(a)

[a] Insufficient sampling data to provide a meaningful annual average.

Measurements on traverses across the river at Richland indicate a slightly nonuniform distribution of the longer-lived radiosotopes at this cross-section. Entries of the Yakima River some 16 km (10 miles) above Pasco and of the Snake River some 48 km (30 miles) above McNary Dam slightly influence the distribution of radionuclides below these two points. The magnitude of the influence varies with seasonal changes in the flow rate of the tributaries. Bonneville Dam is approximately 490 km (305 miles) below the Hanford reactors and represents the furthest downstream location where river water is routinely sampled for Hanford's environmental surveillance program.

Although transport rates at Richland in 1967 for phosphorus-32, chromium-51, and zinc-65 exceeded 1966 values, chromium-51, and zinc-65, transport rates were lower than in 1965 or 1964; phosphorus-32 transport rates were similar to those of past years. The annual average transport rate of selected radionuclides past the Bonneville Dam is given in table 2.

Table 2. Annual average transport rate past Bonneville Dam of selected radionuclides, 1964–1967

Radionuclide	Transport rate (Ci/day)			
	1964	1965	1966	1967
Phosphorus-32	12	11	9	12
Chromium-51	860	800	430	610
Zinc-65	44	49	21	40

An estimate of the inventory of those radionuclides which exist in the ocean may be calculated by assuming an equilibrium between the rate of addition from the river and the rate of decay in the ocean. A constant rate of entry into the ocean equivalent to that indicated by the 1967 Bonneville Dam measurements would imply an inventory of about 250 curies of phosphorus-32, 24,000 curies of chromium-51, and 14,000 curies of zinc-65.

Radionuclides in drinking water

The city of Richland is the first community downstream from the Hanford reactors that uses the Columbia River as a source of drinking water. Pasco and Kennewick, a few miles farther downstream, also use the Columbia River as a source of drinking water. Continuous potable water samples were collected at the Richland and Pasco water plants, and periodic samples were collected at Kennewick. All of these samples were analyzed for the important individual radionuclides. The results of analyses of drinking water from these three cities are summarized in table 3.

The concentations of short-lived radionuclides in the water at the time it is consumed are less than shown in table 3 because there is a significant transport time between the water plant and most consumers. The transport time may vary from hours to days depending upon the location of customers on the distribution system and the water demand.

Table 3. Annual average concentration of radioactivity measured in drinking water, 1967

Radionuclides	Radioactivity concentration (pCi/liter)		
	Richland	Pasco	Kennewick
Rare earths + yttrium	87	46	[a]
Sodium–24	1,700	790	94
Phosphorus–32	58	52	15
Chromium–51	3,100	2,700	1,200
Copper–64	570	160	44
Zinc–65	86	65	<20
Arsenic–76	160	56	16
Strontium–90	1	1	[a]
Iodine–131	8	6	<2
Antimony–122	140	120	18
Neptunium–239	600	420	55

[a] Insufficient data to provide a meaningful annual average.

The calculated annual average dose to whole body, the GI tract, and thyroid, and the percent maximum permissible rate of intake (MPRI) for bone from sustained consumption of drinking water throughout the year are presented in table 4 for the three cities.

Table 4. Calculated annual dose for selected organs from routine ingestion of drinking water, 1967[a]

Location	Whole body (mrem)	GI tract (mrem)	Bone (percent of MPRI)	Thyroid small child (0.4 liter/day) (mrem)
Richland	1.7	28	0.5	41
Pasco	1.1	15	.1	35
Kennewick	<1	2.8	<.1	13

[a] Here and elsewhere in this report where a dose (mrem) from an ingested nuclide is expressed, the determination is made from parameters used by the ICRP to translate dose rates into maximum permissible concentrations for drinking water. In most cases, the estimated annual intakes of individual radionuclides were multiplied by conversion factors derived from the ICRP parameters and published by Vennart and Minski (*2*).

Note: The "standard man" average intake rate of 1.2 liter/day was used in this calculation (*3*).

The estimated GI tract dose to Pasco residents from the measured radionuclides in drinking water was somewhat higher in 1967 (15 mrem) than in 1966 (11 mrem) because of the extended shutdown of all reactors during the summer of 1966 (*4,5*). However, the calculated GI tract dose for Richland residents was lower in 1967 (28 mrem) than was reported for 1966 (34 mrem). The major reason for the apparently reduced dose at Richland was a change in the basis for the calculation. Measurements from a continuous monitor of gross radioactivity in the Richland drinking water were substituted during part of the year for complete reliance on periodic "grab" sampling. The infant thyroid dose appears somewhat higher during 1967 than during 1966 (*6*) because a contribution from iodine-133 was included in the 1967 estimate. Without the increment from iodine-133, the estimated thyroid dose for 1967 would have been lower than for 1966.

Radionuclides in Columbia River fish

The quantities and kinds of fish caught by local fishermen have been previously estimated from surveys carried out from 1963 to 1965 in cooperation with the Washington State Game Department. The maximum estimate of consumption by the fishermen interviewed was 200 meals/yr of panfish species (crappie, perch, and bass) taken from the Columbia River.

From this species distribution and radiochemical analyses of the specimens collected (*7*) the maximum fish consumer would have received intakes during 1967 of 1.6 μCi phosphorus-32 and 0.4 μCi zinc-65. Such an intake would have amounted to 10 percent of the maximum permissible intake with bone as the critical organ. Comparable values for 1966 were 1.0 μCi phosphorus-32 and 0.5 μCi zinc-65.

The average consumption of Columbia River fish by Richland residents was estimated from plant employee diet questionnaires. With the use of the same mixture of species as for the maximum fish consumer, the average intake during 1967 was 0.019 μCi phosphorus-32 and 0.004 μCi zinc-65, or about 0.1 percent of the MPRI with bone as the critical organ.

Radionuclides in shellfish

Zinc-65 and phosphorus-32 are the only radionuclides in the reactor effluent that are found in sufficient abundance beyond the mouth of the Columbia River to be of radiological interest. Oysters have been found to contain higher concentratons of zinc-65 than other common seafoods. In the case of phosphorus-32, a normal seasonal minimum occurs in the late summer. In August 1967, phosphorus-32 concentrations were below 1 pCi/g and remained at this low level through December. The annual average concentrations of 30 pCi/g of zinc-65 and 3.3 pCi/g phosphorus-32 for 1967 were similar to those of 1966.

Consumption of oysters containing these concentrations at the rate of 50 g/day (*8*) would result in an annual dose of about 6 mrem to the GI

tract and 4 mrem to the whole body. These intakes represent 0.4 percent of the MPRI for bone as the critical organ.

Radionuclides in the atmosphere

At Hanford, gaseous waste from the chemical separation facilities is released to the atmosphere through 70 m high (230 feet) stacks after most of the radioactive materials have been removed by filtration and scrubbing. These radioactive materials are primarily associated with process vessel off-gases. Ventilation air from laboratory and reactor building contains comparatively minor amounts of radioactive materials under normal operating conditions.

Measurements of airborne iodine-131 were made routinely at numerous locations within the Hanford reservation and around the plant perimeter. The results of iodine-131 measurements for the past few years are summarized in table 5.

The four locations listed in table 5 lie within a 45° sector southeast to south of these separations center. Such concentrations sustained in inspired air imply an annual dose to the thyroid of the "standard man" of less than 1 mrem.

Table 5. Annual average iodine-131 concentrations in the atmosphere 1964–1967

Location	Distance from separation stacks (miles)	Iodine-131 (pCi/m)			
		1964	1965	1966	1967
Prosser barricade[a]	14	0.02	0.03	0.02	0.02
Benton City	20	.06	.03	.01	.02
Richland	23	.02	.02	.01	.02
Pasco	32	.01	.03	.01	.02

[a] Installed during October 1963.

Air filter sampling is maintained at several locations within the Hanford reservation and around the plant perimeter. Air filter results are not used in estimating exposure but serve to illustrate the trends in atmospheric contamination. Sudden changes in concentration are used to signal the need for shifted emphasis in other portions of the environmental monitoring program related to atmospheric contamination.

Radionuclides in milk and produce

The radioactivity found in locally grown agricultural produce can be influenced by deposition of airborne radionuclides or by irrigation with river water containing reactor effluent radionuclides. The chemical separations facilities are generally the principal local source of airborne radionuclides. The closest farming area to the separations facilities is about 21 km (13 miles) away.

Most irrigated farms near the Hanford plant use water drawn from the Yakima River, or from the Columbia River above the project. There are, however, two small areas which regularly take water from the Columbia River downstream from the reactors for irrigation. They are the Ringold farms and the Riverview district west of Pasco, located respectively 25 and 40 miles downstream from the reactors.

The principal products from the larger farm plots are hay, fruit, beef, and dairy products. This area is centered 48 km (30 miles) southeast of the chemical separations plants. Another agricultural area near the project is Benton City, located on the Yakima River about 20 miles (32 km) directly south of the separations facilities.

The milk surveillance program maintained during 1967 included samples from local farms and dairies and from commercial supplies available to people in the tri-cities. The concentrations of radionuclides found in milk sold by commercial outlets were similar to that reported by the U.S. Public Health Service and the Washington State Department of Health. Milk from local farms irrigated with water drawn from the river downstream from the reactors contained phosphorus-32, zinc-65, and iodine-131, as well as fission products of fallout origin.

Generally, the average concentration of iodine-131 in both local and commercial milk was near or below the analytical limit of 3 pCi/liter, except for a sharp increase during an influx of fresh fallout in January. Brief increases were noted in May following small transient increases in the release rates of iodine-131 from a chemical separations facility. The average concentration of iodine-131 in milk observed for the year was 4 pCi/liter.

Dairy farms in the Ringold and Riverview area that utilize the Columbia River for irrigation of pasture land and hay fields produce milk containing both phosphorus-32 and zinc-65. During 1967, the average concentration of phosphorus-32 in milk from Ringold and Riverview farms was 320 pCi/liter and the average concentration of zinc-65 was 200 pCi/liter. Commercial milk distributed in the Tri-Cities usually does not

contain detectable phosphorus-32 and zinc-65 because it is obtained principally from farms not irrigated with Columbia River water.

Adult residents consuming milk (1 liter/day) obtained from the Ringold-Riverview area would receive an annual dose from phosphorus-32 and zinc-65 amounting to about 3 mrem to the GI tract and 1.3 mrem to the whole body. The intake of phosphorus-32 and zinc-65 would be equal to about 0.7 percent of the MPRI for bone. The intake of iodine-131 would have resulted in a dose of about 25 mrem to the 2 g thyroid of an infant.

Miscellaneous fresh farm produce was sampled periodically for radioanalysis during the 1967 growing season from local farms and commercial outlets. Results of these measurements were similar to those of previous years (*4–5*) and indicated that only small quantities of radionuclides are present in locally-grown produce.

The concentrations of iodine-131 found in samples of fresh vegetables collected from local farms and markets during the period of May through September 1967 were less than or approximately equal to the analytical limit of 0.05 pCi/g. If these fresh vegetables had been consumed at the rate of 100 g/day throughout the 5-month period the average intake from this source would have been about 380 pCi for iodine-131, based on an assumed average concentration of 0.025 pCi/g. Such an intake would imply an annual dose of about 0.6 mrem to the thyroid of an adult. An intake of 50 grams per day of the same vegetable by a small child would imply an annual dose of about 4 mrem to a 2 g thyroid.

Concentrations of iodine-131 in cattle thyroids

Thyroids of cattle are collected periodically from slaughter houses in Moses Lake, Yakima, Walla Walla, Wenatchee, and Pasco, and are sent to Hanford for radioanalysis. The maximum concentration of 160 pCi iodine-131/g of thyroid was a single sample collected in January 1967 at Walla Walla following an announced foreign nuclear weapons test.

External radiation

Ionization chambers are stationed on the Hanford reservation and in Richland to estimate the gamma radiation exposure from external sources. Measurements in air 1 meter above ground during 1967 averaged about 0.35 mR/day or 130 mR/yr at Hanford and about 0.26 mR/day or 100 mR/yr at Richland. Essentially all of the exposure is from natural background and worldwide fallout from nuclear weapons testing.

Direct radiation measurements are also made in the Columbia River at several locations with pocket-type ionization chambers submerged 0.6 to 1.5 meters (2 to 5 feet) below the surface of the water. Exposure rates are higher in the river than over ground because of the presence of gamma-ray emitters (especially sodium-24) in reactor effluent. In the vicinity of Richland, the average exposure rate in the water during the months of April through October was about 2.5 mR/day. A person swimming or boating in the river for a total of 240 hours during the year could have received a whole-body exposure of 25 mR.

An estimate of the external radiation exposure received by people that fish from the shore in the vicinity of the Hanford project is made from routine measurements at the river shoreline. Recent measurements of the gamma-ray spectrum indicate that zinc-65 and scandium-46 accumulated by algal growth on the substrate at the river's edge is responsible for a major portion of a fisherman's radiation exposure. Assuming that an avid fisherman spent as many as 500 hours on the river bank in the vicinity of Richland during 1967, his external exposure could have been about 11 mR.

Radioactivity in ground water

Depending upon their burden of radionuclides, liquid wastes from the chemical separations areas are routed to various facilities. High-level wastes are stored in underground concrete tanks lined with steel. Intermediate-level wastes are sent to underground "cribs" from which they percolate into the soil. The areas selected for intermediate waste disposal and high-level waste storage have soil with good ion exchange capacity and ground water depths of 50 to 100 m (165 to 330 feet). Low-level wastes (usually containing <50 pCi/ml) are sent to depressions in the ground where surface ponds or "swamps" have been formed as a result of the continuous addition of the relatively large volumes of water. Wells have been drilled in and around crib and tank storage areas to detect any leaks in the tanks and to measure radionuclides that have reached the ground water.

The bulk of this radioactive material is hydrogen-3 and ruthenium-rhodium-106.

In all probability, some radionuclides from the chemical processing areas are now entering the Columbia River. However, the contribution of these nuclides is too small to be detectable in the river water and any exposure from them is therefore negligible.

Fallout from nuclear weapons testing

In addition to the radiation dose received by residents of the Hanford environs from Hanford-originated radionuclides and from natural background radiation, a dose increment due to fallout nuclides is also received. Locally this increment is below the national average because of the low rainfall in this region (6.3 inches/year). Measurements of fallout, like measurements of natural background radiation, are necessary to place the radiation dose resulting from Hanford operations into proper perspective. Table 6 shows a summary of the estimated annual doses from fallout nuclides present in the Hanford environs. The MPRI's for strontium-90 are derived from Federal Radiation Council Guides (*9*).

Table 6. Annual radiation dose from fallout radionuclides, 1967

Radionuclide	Organ	Radiation dose (mrem)		
		Maximum individual	Typical Richland resident	Average Richland resident
Tritium	Whole body	<1	<1	<1
Strontium-90	GI tract	<1	<1	<1
	Whole body	3	3	<2
	Bone	(1 percent MPRI)	(4 percent MPRI)	(3 percent MPRI)
Cesium-137	GI tract	<1	<1	<1
	Whole body	2	<1	<1
	Bone	(0.2 percent MPRI)	(0.1 percent MPRI)	(0.1 percent MPRI)

The maximum individual

Experience accumulated from the environmental surveillance program and associated research studies indicates that those individuals receiving the greatest percentage of permissible radiation dose from Hanford sources, the "maximum" individual, consume some combination of the following: fish caught locally in the Columbia River; game birds shot near the river; foodstuffs produced on local farms irrigated with Columbia River water drawn from below the reactors; and municipal water with the Columbia River as the source.

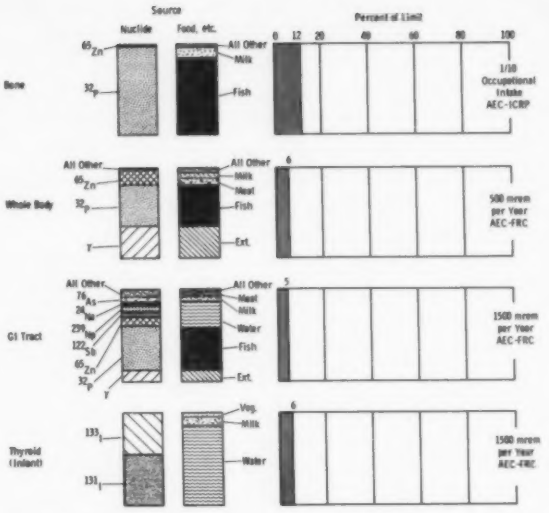

Figure 2. Estimated dose to "maximum" individual

The composite dose for this "maximum" individual is summarized in table 7 (figure 2). Estimated doses to the GI tract for the "maximum" individual during 1967 and 1966 were both about 5 percent of the appropriate limit, with phosphorus-32 contributing about 50 percent of the total dose in each case. The 1967 GI tract dose was 82 mrem. For the whole body dose, 32 mrem or about 6 percent of the appropriate limit, the 1967 estimate was not significantly different from the 1966 estimate of 31 mrem. The estimated percent of the maximum permissible rate of intake for bone as the critical organ was 12 percent during 1967, compared to 10 percent for 1966.

In the case of the thyroid gland, the highest radiation doses are those received by infants because of the relatively small thyroid mass (assumed to be 2 g). This value is similar to the maximum infant thyroid dose estimated for 1966. However. the estimates are not directly comparable, because estimates of thyroid dose for 1967, unlike that for 1966, included contributions from both iodine-131 and iodine-133 in the drinking water. The estimate of iodine-133 intake by the maximum Richland infant gave a contribution to the thyroid dose of 47 mrem for 1967 or about one-half of the total.

Table 8 shows the trend of "maximum" individual dose estimates for the period 1964-1967.

Table 7. Summary of radiation doses in uncontrolled areas of Hanford environs 1967[a]

Organ	Maximum individual			Typical Richland resident		
	Annual dose (mrem)	Limit (mrem)	Percent of limit	Annual dose (mrem)	Limit (mrem)	Percent of limit
GI tract	82	1,500	5	24	500	5
Thyroid (infant)	97	1,500	6	50	500	10
Whole body	32	500	6	4	170	3
Bone	[b]	[c]	12	[b]	[d]	.6

[a] Represents individuals or population groups residing in uncontrolled areas near the Hanford plant.
[b] Bone dose not calculated. Exposure relative to permissiible exposure determined on the basis of MPRI.
[c] ICRP MPRI for "maximum individual"—16 μCi ^{32}P/yr and 800 μCi ^{65}Zn/yr.
[d] ICRP MPRI for "typical Richland resident"—5.3 μCi ^{32}P/yr and 270 μCi ^{65}Zn/yr.

Table 8. Dose estimates for maximum individual,[a] 1964 to 1967

Organ	Percent of limit				Limit (mrem)
	1964	1965	1966	1967	
GI tract	9	6	5	5	1,500
Whole body	18	8	7	6	500
Bone	23	12	10	12	
Thyroid (infant)	5	4	6	[b] 3	1,500

[a] Does not include fallout and natural background.
[b] For comparison, includes dose from iodine-131 only.

The 1967 thyroid dose has been adjusted to a comparable basis (from iodine-131 only). The increase observed in the thyroid dose during 1966 reflects an unusual release of radioiodine to the Columbia River from a production reactor (*9*). The long trend for whole body and GI tract doses is obviously downward. Bone doses for the "maximum" individual, which appear to have leveled off at about 10 to 12 percent of the MPRI for the past 3 years, are heavily dependent upon phosphorus-32 concentrations in Columbia River fish. The latter concentrations are, in turn, dependent on river conditions as well as radionuclide release rates. The 1966 estimate reflects, to some extent, the extended reactor outage of that year (*9*).

The typical Richland resident

The majority of people who live in Richland obtain their food from local commercial stores (rather than from farms) and consume little or no Columbia River fish or local game birds. The principal soure of radionuclides of Hanford origin ingested by such people is drinking water obtained from the Columbia River. For continuity with previous years, the doses for several organs of the body for the typical Richland resident have been calculated for 1967 (table 7 and figure 3).

For comparison, whole body doses from natural background and from fallout in this region are estimated at about 100 mrem/yr and 3 mrem/yr, respectively.

Conclusion

During 1967, the environmental surveillance program of the Hanford environs again showed that

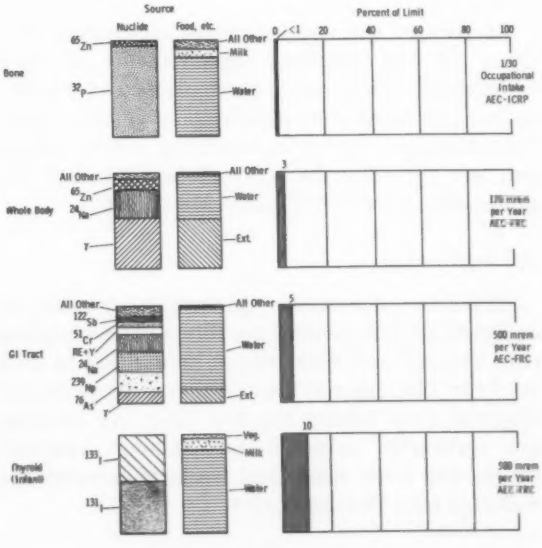

Figure 3. Estimated dose to "typical" Richland resident

the amounts of radioactive materials present were well within nationally accepted limits at all times. The only estimate exceeding one-tenth of the appropriate limit was 12 percent MPRI for the bone of the hypothetical "maximum" individual. Because of the 1966 reactor outage, some 1967 dose estimates for the environmental population exceeded 1966 levels, but not 1965 levels. The shutdown of plant facilities and process improvements have both contributed to a decrease in most dose estimates from 1965 to 1967.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
Calendar year 1966	February 1968

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2. Los Alamos Scientific Laboratory[3] Calender Year 1968

University of California
Los Alamos, New Mexico

As part of the environmental monitoring program at Los Alamos, measurements of beta radioactivity in airborne particulates and precipitation are made periodically. The samples have been taken on the roof of building TA-50 (about one and three-fourths of a mile southeast of the administrative building) since March 1963.

Air monitoring

Airborne radioactive particulate matter is collected on 4-inch-diameter filters. The sampling rate was reduced from 46 m^3/hr in 1962 to 25.5 m^3/hr in 1963, due to the addition of an activated charcoal filter behind the first filter. Air samples are ordinarily collected for 24-hour intervals during the work week, and weekend samples are collected for a 72-hour period.

[3] Summarized from "Beta Radioactivity in Environmental Air and Precipitation at Los Alamos, New Mexico, for 1968" (LA-4133).

The filters are counted for beta radioactivity 7 days after collection in a thin-window gas (methane) flow proportional counter with an overall efficiency of 50 percent for strontium-yttruim-90.

Precipitation monitoring

Collection is made in a 0.4 square meter rain collector which delivers 1 liter of water for each 0.1 inch of precipitation. It has been found that this arrangement collected radioactivity even during relatively dry periods. By washing down the sides of the collector with 1 liter of distilled water, a suitable sample is obtained. These "wash" samples, as well as any precipitation, are reduced in volume, dry-plated on 1-inch stainless-steel planchets, and counted in an automatic beta-particle system, employing a gas-flow proportional, alpha and beta chamber. A cosmic-ray umbrella with coincidence counter cancel provides a low background for the system.

Results

Average daily radioactivity concentrations for air collected are weighted for sample periods of more than 1 day. Average radioactivity concen-

trations for the precipitation collection are calculated from the total radioactivity collected during the month divided by the number of days in the month. Summary of air data (pCi/m^3) shows the maximum, 1.45; minimum, 0.01; and average 0.17. Precipitation data (nCi/m^2) shows the maximum, 9.2; minimum, 0.001; and average, 3.2.

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